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CIVIL DEFENSE MEDICAL SERVICE TRAUMATOLOGY HANDBOOK

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ANNOTATION

This handbook presents the fundamental principles of modern traumatology in application to the tasks and working conditions of civil defense medical service institutions. Part One devotes its main attention to organizing traumatological care to casualties in major disasters and to their medical sorting at the civil defense medical service's evacuation stages--first aid detachments and specialized hospitals. The problems of preventing and treating traumatic shock and the specific features of its diagnosis in the presence of compound injuries and among elderly and senile persons are discussed in light of modern concepts.

Chapters devoted to wounds and wound infection reflect the premises of prevention and treatment of wound infection in the stage-by-stage treatment system. Special attention is turned in the presentation of the principles of treating thermal injuries to the unique features of care rendered to persons injured by light radiation and burning mixtures. A special chapter deals with the principles of treating and preventing complications arising in the presence of radiation burns.

Part Two of the handbook is devoted to the problems of particular traumatology. The basic premises on the clinical pattern of injuries, the unique features of rendering first aid, on sorting, on prephysician's and physician's care, and on the basic principles of specialized treatment applicable to injuries of the head and neck, the abdomen, the pelvis and pelvic organs, the spine and spinal cord, and the limbs (including major vessels and nerves) are successively presented. Part Three examines the basic concepts of combined injuries--mechanical injuries and burns combined with acute radiation sickness, and injuries and burns contaminated by products of a nuclear burst. A separate chapter deals with the course and principles of treatment applicable to the combination of mechanical traumas and thermal injuries.

The book is intended for surgeons, traumatologists, stomatologists, neurosurgeons, otolaryngologists, and public health organizers.

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FOREWORD

World War II ended 50 million human lives. The concluding stage of the war was marked by appearance of nuclear weapons. Atomic bombs dropped by the Americans in 1945 on the Japanese cities of Hiroshima and Nagasaki transformed them into heaps of ruins; the losses suffered by the public totaled hundreds of thousands of dead and wounded. Since that time, nuclear weapons have been undergoing continual improvement, their power has risen, and modern missiles carrying nuclear warheads can deliver them to any target on the globe within a short time.

Availability of nuclear weapons to aggressive imperialist states and the possibility for their use in the event of initiation of World War III make preparations for our country's protection a priority task of national importance.

The Soviet Union is persistently fighting to limit arms, to prohibit nuclear weapons, and to maintain peaceful coexistence. At the same time the Communist Party and the USSR government view protecting the socialist fatherland and strengthening the defense capabilities of the USSR and the power of the Soviet Armed Forces as a sacred duty of the party and all Soviet people, as the most important function of the socialist state.

Use of nuclear weapons having tremendous destructive power will mean considerable losses in the population. In this connection Soviet public health and the USSR Civil Defense Medical Service, which is intended to render aid in areas of mass destruction, face a great, complex problem--implementing a complex of preventive, therapeutic, and evacuational measures with the goal of providing modern medical care to the stricken public, providing specialized therapy to casualties, and reducing mortality and disability caused by wounds and diseases.

A nuclear strike will be accompanied by concurrent arisal of tremendous numbers of wounded individuals, burn victims, and individuals with combined injuries. At the same time the manpower and facilities of the medical service will be extremely limited, and the working conditions will be extremely unfavorable. In this connection much attention must be devoted to the problem of wartime injuries and their treatment, and to organizing traumatological aid to casualties.

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Wartime traumatology is not a narrow concept limited to the treatment of injuries to the locomotor-bearing apparatus; instead, it is a broad complex of scientifically grounded theoretical, practical, and organizational premises embracing the problems of pathology, clinical pattern, and treatment of casualties at times of instantaneous arisal of massive traumatic injuries.

The goal of this traumatology handbook is to help the civil defense medical service to achieve a certain degree of compliance with all of the requirements and features of treating casualties at the evacuation stages of the civil defense medical service. This handbook examines the organization of surgical aid on analogy with corresponding manuals of military field surgery. The difference lies in the fact that treatment is examined only in two evacuation stages: In the first stage, at first medical aid detachments and surviving therapeutic institutions, casualties are rendered first physician's aid; in the second stage casualties receive specialized medical aid in specialized hospitals of a hospital base until a stable outcome of therapy is achieved.

This handbook of military traumatology for the civil defense medical service is being published for the first time on the basis of an analysis of extensive materials, the experience of Soviet medicine in the Great Patriotic War, and the personal experiences of the authors.

The author collective believes that the present work will help improve preparation of medical personnel for work in the civil defense medical service.

Distinguished Scientist,
Prof A. I. Kaz'min

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PART ONE

GENERAL PROBLEMS OF MILITARY TRAUMATOLOGY

CHAPTER 1

ORGANIZATION OF TRAUMATOLOGICAL CARE FOR CASUALTIES IN MEDICAL EVACUATION STAGES

General Principles of Rendering Aid

A drastic inconsistency between the manpower and resources available to the civil defense medical service and the number of medical losses will have an influence on the way the work of the medical service is organized. The principles and content of surgery will depend on important features of pathology differing dramatically from the pathology of peacetime, and on the number of casualties arriving at a particular evacuation stage in a short interval of time, which will be substantial.

As we know, N. I. Pirogov called war a "traumatological epidemic," desiring to emphasize by this that tremendous numbers of traumas are encountered only at times of war. Use of nuclear missiles will cause an "epidemic" of the most diverse open and closed wounds, burns, radiation injuries and, finally, the most diverse combined injuries. Treatment of such casualties requires integrated therapeutic-diagnostic measures implemented in coordinated fashion by physicians of different specialties, mainly surgeons and therapists. The need arises for expanding the volume of therapeutic measures and significantly increasing the outlays of time and resources for their implementation, which will doubtlessly make rendering all forms of aid (prephysician's, physician's, and specialized) and therapy complicated.

The conditions under which the civil defense medical service will have to work (the massive numbers of medical losses, the unique features of battle pathology, and restricted possibilities and great difficulties in organizing aid to casualties) bring the organizational and surgical principles of its work close to the fundamental premises of military field surgery. This is why the civil defense medical service makes maximum use of the wise experience and fundamental principles of modern military field surgery.

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These principles could be worded as follows in relation to the civil defense medical service.

1. Organizational measures must be implemented to ensure provision of aid and stage-by-stage treatment in the face of an instantaneous, massive arrival of casualties. In these conditions the lack of medical personnel, surgeons especially, transportation resources, shelter, and medicines needed for reception of casualties and provision of aid to them manifests itself especially dramatically. If we are to promptly render the most effective surgical aid to a large number of casualties under these conditions, just proficiency in surgical techniques, the methods for applying dressings or temporary splints, and blood transfusion methods alone would be totally insufficient. The main task is to competently organize the work of all functional subdivisions of the medical institution (the OPM [first medical aid detachment], out-of-town hospital).

The work should be organized in such a way that no matter what the situation, the best conditions for rendering the necessary aid to casualties, emergency aid primarily, would be ensured.

2. When massive medical losses occur, medical sorting acquires special significance. Medical sorting must ensure favorable conditions for the most sensible utilization of surgical manpower and the most effective and timely provision of medical aid to the largest possible number of casualties, in a particular order of priority.

3. The amount of surgical aid rendered depends on the stage of medical evacuation. Hospital collection centers in the out-of-town zone will be the principal therapeutic base of the civil defense medical service. But in order that safe evacuation of casualties for great distances could be ensured, first physician's and surgical aid must be rendered on the basis of vital indications in the first stage of medical evacuation--in the first medical aid detachment (OPM).

4. One of the main principles is the strictest possible observance of continuity in casualty treatment at different stages of medical evacuation. Rendering medical aid and treating casualties in a stage-by-stage therapeutic system would inevitably mean treatment by a succession of physicians. When organization is inadequate, this circumstance could also mean an irrational succession of different treatment methods. When the principle of continuity is observed, the content of the medical aid would naturally be consistent and, when necessary, it will be expanded as required; in this case treatment initiated in one stage of medical evacuation will continue on in the future in compliance with the unity of the principles and methods of treatment. Continuity could be attained in treatment on the condition that both stages of medical evacuation of a given medical-evacuation specialization are under a single command, and if all work is based on common principles of casualty treatment. This is achieved with a unified medical-evacuation organization and standardized directives on the treatment of

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injuries in different stages of medical evacuation, clearly formulated on the basis of the experience of the Great Patriotic War and the achievements of modern medical science.

5. Continuity in casualty treatment would be impossible without precise medical documentation ensuring that physicians in the next stage of medical evacuation would receive the information they need, such as the particular wound discovered on the casualty and the sort of aid rendered to him in the previous stage (in the OPM). All notes must be maximally clear and brief.

6. A certain volume of aid--that is, a list of therapeutic-preventive measures that must be implemented in the given stage--is established for every stage of medical evacuation.

When the demand for surgery is high, the volume of surgical aid rendered depends intimately on the evolving medical situation. When very large numbers of casualties arrive at the given stage of medical evacuation, obviously exceeding its "traffic capacity," the volume of aid is limited to the simplest manipulations aimed at keeping casualties in critical condition alive. On the other hand when the flow of casualties is relatively light the volume of aid could include the entire list of measures for which the given stage is suited. Thus when the demand for surgery is high its content depends not only on the nature and severity of wounds but also on the working conditions of the medical institution operating as a medical evacuation stage.

7. As a rule when massive casualties require aid, the medical institution will have to be organized anew, often in ill-suited quarters and in extremely short time. This means that the personnel of such institutions will have to have good practical skills and the ability to adapt and incorporate various sorts of shelters, quickly outfit them and put them in working order, create aseptic conditions in surgical and dressing wards, and use a limited assortment of tools, instruments, medicines, and dressings.

Three forms of medical aid are distinguished in the stage-by-stage treatment system--first medical aid, first physician's aid, and special medical aid.

First aid and mutual aid are rendered within the disaster center by the victims themselves (self-aid) or surrounding individuals (mutual aid), as well as by the personnel of medical teams. Special emphasis should be laid on the fact that self-aid and mutual aid acquire special significance in regions of destruction, since the life of the casualty and the further course of pathological processes often depend on the quality of this aid.

Medical and special personnel working in an area of massive losses render aid mainly to seriously injured casualties. As a rule light casualties must obtain first aid as self- and mutual aid.

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First aid consists of the following measures:

Temporary stoppage of external bleeding;

elimination of the causes of asphyxiation or encumbered breathing (removal of foreign bodies and dust from the mouth cavity and nose), fixation of the tongue when the casualty is unconscious, artificial respiration, and application of an airtight dressing over an open pneumothorax;

application of dressings to wounds and burned surfaces;

immobilization of fractured bones and areas of extensive damage to soft tissues to permit transportation;

artificial respiration;

partial decontamination;

placement of a gas mask or cotton gauze mask over the casualty's face if he is in a zone of radioactive contamination;

evacuation of casualties from a contaminated zone.

Implementation of these relatively simple measures has a very great influence on the course and final outcome of injuries.

Special attention should be turned to promptly stopping external bleeding. Sources of such bleeding can include massive lacerations, contusions, and incised wounds made by glass fragments (these injuries will be encountered rather often). A standard or improvised tourniquet is applied to stop external arterial bleeding. Venous bleeding is stopped as a rule by applying a pressure bandage. An applied tourniquet must be well noticeable: It should not be covered over by a dressing or clothing. The time of the tourniquet's application must be noted. When asphyxiation is caused by the swallowing of the tongue (the casualty is unconscious), the casualty's tongue must be arrested by suturing it down along the midline with a ligature. When the nasal passages and mouth cavity are mechanically obstructed, they must be cleared out immediately. If independent breathing is not resumed, artificial respiration using one of the existing methods must be started.

Application of an initial dressing prevents secondary contamination of the wound by microbes and helps to stop bleeding. Individual dressing packs or sterile bandages can be used. To cover burned surfaces, it would be desirable to use special shaped dressings.

Immobilization of a fractured spine, pelvis, and limb bones, and of extensive areas of soft tissue damage to permit transportation is a mandatory element of first aid. Such immobilization can be achieved with standard splints or splints improvised out of available resources. More-primitive but

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sufficiently effective means of immobilization should be remembered--fixing an upper limb to the torso, and tying a damaged lower limb to the intact leg with soft material.

All casualties requiring medical aid are sent from the disaster center to an OPM. Strict continuity in evacuation must be observed in this case. Casualties with tourniquets, unconscious casualties, persons with severe breathing disorders, and persons with abdominal injuries are sent to an OPM on first priority. All other casualties are evacuated on second priority. Light casualties travel to an OPM on their own in groups.

The OPM implements the following measures:

Reception, registration, medical sorting, and personal cleansing of casualties;

partial or complete personal cleansing;

provision of first physician's aid;

provision of some skilled medical aid in urgent cases (as determined from vital signs);

hospitalization and temporary treatment of nontransportable casualties;

preparation of casualties for evacuation into the hospital zone.

First physician's aid consists of a broad complex of measures aimed at controlling bleeding and asphyxiation, prevention and treatment of traumatic shock and traumatic toxicosis, and prevention of disturbances in the functions of vitally important organs and infectious complications.

The volume of first physician's aid rendered at at an OPM includes:

1. Surgery on the basis of vital indications (stopping bleeding by applying a ligature to a vessel, applying a tracheostoma).

2. Replenishment of lost blood (mainly with blood substitutes).

3. Novocaine blockade in the presence of chest and limb injuries complicated by shock.

4. Application of an occlusive dressing in the presence of an open pneumothorax.

5. Puncture of the pleural cavity or thoracentesis in the presence of tension (valvular) pneumothorax.

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6. Catheterization or puncture of the urinary bladder in cases of urine retention.

7. Immobilization of fractured bones and extensive areas of damage to limb soft tissues to permit transportation.

8. Administration of general anesthetics, cardiac agents, antibiotics, anatoxins, and tetanus serum, in accordance with the indications.

Surgery categorized as skilled surgical care must be rendered on the basis of vital indications in the surgical ward of the OPM.

Surgery required by vital indications includes:

Tracheostomy in the presence of asphyxiation caused by wounding of the face or neck, or serious injury to the chest;

suturing of an open pneumothorax if sealing with an occlusive dressing is ineffective;

thoracentesis and drainage of the pleural cavity in the presence of tension (valvular) pneumothorax, if the latter cannot be corrected by puncture of the pleural cavity;

puncture of the pleural cavity and aspiration of blood in the presence of massive hemothorax eliciting serious disturbances in breathing and cardiac activity;

laparotomy in the presence of damage to intraperitoneal organs (intraperitoneal hemorrhaging);

final stoppage of bleeding (by ligation of the vessel) when external bleeding continues;

amputation of clearly irreparable limbs.

Casualties are evacuated into the out-of-town zone in transportation specially allocated for this purpose. Casualties must be loaded aboard the vehicles with a consideration for their evacuational destination.

Specialized medical aid is rendered and casualties are subjected to specialized treatment until full recovery in therapeutic institutions of the hospital base (of the out-of-town zone).

Casualties are given the full volume of specialized aid and therapy in hospitals of the out-of-town zone, with all therapeutic and diagnostic measures indicated for the given injury being carried out.

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If the tactical medical situation evolves unfavorably the volume of aid rendered in specialized institutions can change to correspond to the volume of first physician's aid. As an example, when massive numbers of casualties arrive in a specialized hospital in the out-of-town zone, in the first 2-3 days the volume of aid will be reduced to those measures required by vital indications. As the flow of casualties decreases the work will become more systematic, and consequently it will expand to the full volume of specialized aid.

Organization of First Physician's Aid and Specialized Pharmacological Aid

The success with which surgical aid is rendered to the victims of a nuclear burst will depend significantly on:

Prompt provision of first medical and first physician's aid;

the number of beds available in the therapeutic institutions;

sensible location of the therapeutic institutions;

suitable maneuver of manpower and resources of the medical service in correspondence with the arising situation;

availability of qualified surgeons and traumatologists in the different stages of medical evacuation.

The principal organizational premises of the civil defense medical service are: Utilization of the surgical base existing in peacetime in the therapeutic institutions of public health agencies and other departments, implementation of the principle of stage-by-stage treatment while observing continuity in therapeutic measures, and organization and maneuver of available manpower and resources.

The principles of surgical aid followed in the civil defense system are kindred to the fundamental principles of military field surgery.

First physician's aid and surgical aid based on vital indications are rendered at an OPM. The volume of surgical aid rendered at an OPM is determined by the intensity with which victims arrive and by the availability of medical personnel and medical stock in the OPM. Medical sorting, prevention of wound infection, implementation of antishock measures, final stoppage of bleeding, and other surgical procedures based on vital indications are mandatory in an OPM.

Specialized surgical aid is rendered in the second stage of medical evacuation in the out-of-town zone, where sorting evacuation hospitals (SEG) and main and specialized hospitals are deployed. SEG's and main hospitals provide emergency and specialized medical aid to the victims of a nuclear burst. All

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serious casualties that cannot be evacuated to a specialized hospital without detriment to their condition are concentrated in them.

In specialized hospitals, casualties are rendered specialized aid and treated until the final outcome of injury.

If an enemy uses a nuclear weapon, most specialized hospitals will have a traumatological profile. The following types of hospitals are deployed depending on the forms of injuries suffered by people following a nuclear burst: Burn hospitals--to treat casualties with thermal injuries, traumatological hospitals--to treat persons with injuries to upper and lower limbs, thoracoabdominal hospitals--for casualties with injuries to the rib cage, the abdomen, and organs of the lesser pelvis, and neurosurgical hospitals--to treat casualties with injuries to the skull, spine, ear, nose, throat, eyes, jaws, and face.

Thus the goal of specializing hospitals is to render early specialized aid and organize complete, prompt therapy.

Specialized hospitals servicing the closest SEG or a main hospital make up the hospital collection center. Each hospital collection center is intended for a capacity of several thousand beds, and it is a multiprofile hospital association, making it possible to distribute medical personnel correctly and maneuver reinforcements and medical equipment.

In turn, hospital collection centers are united into hospital bases. A hospital base consists of six to eight hospital collection centers, and its area of service encompasses the entire area in which hospitals are located in the oblast or kray. Hospital bases will play the most important role in rendering specialized aid to casualties in cities subjected to nuclear attack.

In order to achieve efficient organization of all forms of medical aid, including surgical aid, the civil defense medical service creates its own control agencies--MSGO [civil defense medical service] headquarters and hospital base directorates.

The senior surgeons of the union and republic ministries and oblast divisions of public health serve in the union, republic, and oblast (kray) MSGO headquarters. They carry the responsibilities of the official organizers of the MSGO's surgical activities:

Organization of surgical aid in the different stages of medical evacuation;

surveillance over compliance with the principles of stage-by-stage treatment of casualties;

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sensible specialization of the bed pool;

placement of surgical personnel;

utilization of specialized medical aid detachments (teams);

analysis and generalization of the results of surgical treatment rendered to casualties, and preparation, on the basis of the former, of instructions and procedural handbooks;

achievement of compliance with the principles of unified treatment methods, continuity of treatment, upgrading of surgeons through their direct practical participation in the work of surgical institutions and through consultative assistance at the patient's bedside, and discussion of the results of treating and rehabilitating casualties in accordance with the requirements of expert medical certification and the latest achievements of surgical science.

In a two-stage system of medical-evacuation support, the first medical aid detachment (OPM) is the first stage. Being an organic formation of the civil defense medical service, the OPM has a standard manning table, standard equipment, and clearly outlined range of tasks spelled out in special instructions.

The OPM is assigned the tasks of organizing first medical aid in the disaster center, as well as of rendering first physician's aid to victims and preparing them for evacuation to the second stage--the hospitals of the out-of-town zone.

The following subdivisions are deployed in an OPM:

A distributing post, which separates the total flow of casualties in relation to functional subdivisions of the OPM;

a receiving and sorting department;

a surgical and dressing department;

a hospital department.

In the receiving and sorting department casualties are sorted and simultaneously given emergency medical aid. The equipment and gear must permit reception and sorting of all arriving casualties.

Following sorting, casualties can be sent from the receiving and sorting department to the OPM's functional subdivisions--to antishock wards, to the surgical ward for surgery required by vital indications, to the dressing ward to prepare for subsequent evacuation, and to hospital wards for temporary hospitalization. The first three functional subdivisions are organizationally united into the surgical and dressing department.

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Surgeon teams and surgical nurse teams work in the surgical ward. One or two physicians and nurse teams (their number depends on the flow of casualties) work on stretcher cases in the dressing ward, ensuring fulfillment of all required medical procedures. Nurse teams would be sufficient in a dressing ward for ambulatory casualties, on the condition that a qualified paramedic or surgical nurse is assigned to one of the teams. In the necessary cases physicians could be called in from the stretcher case dressing ward for consultation in the dressing ward for ambulatory casualties.

One or two physicians and several nurse teams must work in the antishock wards, ensuring fulfillment of the complex of antishock measures prescribed by the physician.

The surgical and dressing department is deployed in the best-adapted shelters; preoperation and dressing rooms are allocated adjacent to them, and they are outfitted with as many operating or dressing tables as can be serviced by the numbers of surgical teams available. Each team should have two tables, at which they work in succession: At one table they prepare the patient for surgery while at the other surgery goes on at this time.

In addition to operating or dressing tables, the shelters must have tables for surgical instruments and dressings, supports to hold blood and blood substitute transfusion systems, medicine cabinets or tables, water tanks, tubs for washing hands, apron hangers, and so on.

Special equipment must be foreseen for the antishock wards--oxygen dispensing equipment, supports for blood transfusion equipment, artificial respiration apparatus, and so on.

Medical stock and medicines for the surgical, dressing, and antishock wards are foreseen by the equipment table of the OPM.

A hospital department in which one nurse's station is organized for every 50 casualties and to which a physician is assigned, if possible, is deployed for temporary hospitalization of nontransportable casualties and their subsequent preparation for evacuation. Equipment furnished to the hospital department, in addition to stretcher supports, trestle-beds or bunks, and tables for the medical stations is furnished in accordance with the approved equipment table. Lacking medical stores are sought out locally.

The casualty evacuation department is not specifically a surgical subdivision of the OPM, and it provides for the evacuation of the entire flow of casualties as prescribed. Medical workers are not foreseen for its staff. But in a number of cases nurses carrying medical kits will have to be assigned to escort transportation carrying seriously wounded and injured persons.

As was noted above, the structure and tasks of the OPM are specified such that it could render the minimum necessary volume of medical aid with a consideration for swift evacuation of casualties to hospital collection

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centers. However, when evacuation from the OPM is impossible its work is reorganized right as it is operating, making its activity closer to that of a hospital institution. In this case the volume of surgical aid is expanded and, consequently, the surgical and dressing department is reinforced through both internal reassignment of physicians and inclusion of specialized medical aid teams attached to the OPM.

Antishock wards and the hospital department are reinforced mainly by nurses.

The hospital base therapeutic institutions deployed in the out-of-town zone are the second stage of medical evacuation.

The entire volume of specialized medical aid is rendered to casualties in the hospital base (BB). For the most part the personnel and facilities of the existing oblast therapeutic network are used to organize the hospital base. In addition it can be reinforced with additional temporary medical personnel and facilities suitable for deployment of temporary hospitals.

The hospital base consists of several hospital collection centers, each collection center as a rule occupying the territory of one rural rayon. Each hospital collection center contains several specialized hospitals, and it is headed by a sorting and evacuation hospital (SEG) or a main hospital (GB). The composition of a BB also includes hospitals at light casualty collection points, medical distributing points, and evacuation reception points deployed by the sorting and evacuation hospital, and auxiliary distributing posts, if they are deployed by main hospitals.

Specialized hospitals deployed as part of the composition of a hospital collection center have the job of creating the most favorable conditions ensuring prompt provision of specialized medical aid to casualties.

Thus the composition of a hospital collection center contains the following specialized hospitals--neurosurgical, thoracoabdominal, traumatological, a hospital for treatment of wounds to the pelvis and major joints, a hospital for treatment of burn victims, a therapeutic hospital, an infection hospital, a psychiatric hospital, and a hospital for treatment of light casualties.

However, the composition of the hospital collection center may undergo change depending on the operational situation. The activities of the therapeutic institutions of a BB depend significantly on the evolving situation, the quartering conditions, and the availability of personnel and stock.

Specialized hospitals must be specialized therapeutic institutions providing the necessary conditions for hospitalizing and treating casualties of a particular profile, making use of all modern achievements of medical science and practice. Every casualty in such hospitals must be cared for by specialized physicians.

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Inasmuch as most combined injuries are a combination of a surgically-treatable injury and acute radiation sickness or another disease, such casualties must be placed in institutions of a surgical profile. Consequently physicians in surgical hospitals must be ready to receive a significant contingent of persons with combined injuries and a number of therapeutic and other diseases. This in turn requires that the hospitals be staffed with physicians of many specialties or physicians knowing how to handle and correctly treat patients and casualties with the most diverse pathology.

The sorting and evacuation hospital or the main hospital has the objective of sorting casualties and sending them to specialized hospitals, as well as of hospitalizing and rendering emergency medical aid to victims whose condition has deteriorated. Consequently the receiving and sorting department has the dominant significance in the structure of an SEG or a main hospital.

In addition the SEG (GB) deploys a large, well equipped emergency surgical aid department with surgical, dressing, and hospital wards (up to 60 percent of all of the SEG's beds) and an anaerobic department, and up to 10 percent of the beds are allocated to the antishock department.

As a rule the anaerobic department must have its own surgical and dressing wards, while the antishock department must have a manipulation ward with the necessary reanimation equipment. In addition there should be an obstetric department and, among the auxiliary surgical subdivisions, a blood procurement and transfusion station.

The SEG is also given the responsibility of creating specialized medical aid teams of predominantly a surgical profile (neurosurgical, jaw and face, otorhinolaryngological, ophthalmological, thoracoabdominal, burn). They are used both as reinforcements in specialized hospitals and in the SEG itself.

The tasks of the SEG (GB) require that they be staffed by an adequate number of surgeons of broad profile and specialists in traumatology, neurosurgery, urology, gynecology, ophthalmology, jaw and facial surgery, anesthesiology, and reanimatology, as well as medical radiologists, therapists, and infection specialists.

SEG's (GB's) must have well trained surgical and dressing nurses and a sufficient number of orderlies and stretcher-bearers on the staff.

It is on the basis of the important and diverse tasks of the SEG (GB) listed above and the structure of their subdivisions that they are outfitted as necessary to permit them to operate as institutions intended for provision of highly skilled surgical aid of an extremely broad profile--from surgery involving body cavities and traumatology to gynecology and obstetrics.

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Thus a receiving and sorting department must have considerable space and equipment, enough to provide for a large number of injections, dressings, immobilization for traveling, novocaine blockades, and so on.

The surgical and dressing wards of an emergency surgical department of an SEG (GB) must be outfitted, in satisfaction of modern requirements, with an adequate number of operating tables, anesthesiological apparatus, and surgical instruments to render emergency surgical aid on a large scale. The emergency surgical department of an SEG (GB) must have sterilization and autoclave rooms, reserves of oxygen, blood, and blood substitutes, surgical linens, and bandaging materials. The surgical and dressing wards must be furnished with self-contained lighting sources, they must be provided a sufficiently large amount of room, and they must operate on the basis of a flowline system.

Operating tables and instrument kits for traumatological, neurosurgical, ophthalmological, and jaw and face operations as well as a gynecological table must be allocated to surgical wards.

The dressing block must be furnished with cast rooms, stock rooms for procurement and storage of bandaging materials and medicines, and dressing wards servicing persons with thermal injuries.

There should be a radiological office with portable x-ray apparatus in the emergency medical aid department. Here also there should be a blood procurement and transfusion office, a donor station, and a clinical diagnostic laboratory.

In addition to the usual wards, the hospital department must have isolation wards and postoperative wards.

The anaerobic department is housed in a separate block with its own surgical and dressing wards.

Apparatus for massive and lengthy transfusions of blood and blood substitutes, functional apparatus for active and passive stimulation of cardiac and respiratory activity, and the necessary minimum of surgical instruments, bandaging materials, splints, and so on must be concentrated in the antishock department.

The specialized hospital, being the principal therapeutic-preventive institution of the hospital collection center, is intended for hospitalization of casualties, provision of specialized medical aid to them, and treatment of these casualties until the final outcome of disease is achieved. Considering these requirements as well as the massive flow of casualties and the difficulties of providing skilled medical personnel to specialized hospitals, it would be unsensible to create such hospitals with small numbers of beds. The therapeutic process can go on in a hospital with a large number of beds with the help of a smaller number of skilled medical personnel.

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The receiving and sorting department and the surgical and dressing block must be reinforced in the first period of the specialized hospital's activity (the period of mass admissions). This is done by redistributing the medical personnel and equipment of the hospital itself.

In the second period of this activity, when the hospital is completely filled, some of the personnel, shelters, and equipment of the receiving department are transferred to other departments.

Not less than two antiseptic surgical wards and one contaminated surgical ward and several dressing, cast, and manipulation wards are deployed in all specialized hospitals of surgical profile. The surgical and dressing block and the hospital department of a specialized hospital must have all of the apparatus necessary for up-to-date treatment of casualties in accordance with the same requirements imposed on the surgical wards of an SEG (GB).

The success of a specialized hospital's activity depends on presence of a well outfitted clinical diagnostic laboratory, a radiological department, and functional laboratories.

Stiff requirements are imposed on housekeeping support to a hospital. The large volume of surgical activity requires organization of autoclave management, of a sterilization room for surgical instruments, of the procurement and washing of bandaging materials and linens, and so on.

The need for rehabilitating victims will require organization of special subdivisions in the specialized hospital for physiotherapy, work therapy, prosthetics, and teaching the most severely disabled self-care skills.

Specialized medical aid detachments and teams (OSMP and BSMP) are formations of the civil defense medical service. These mobile formations are intended for organization of specialized aid to casualties, including surgical.

The concrete tasks and objectives of the work of OSMP's and BSMP's are determined by the hospital base administration.

BSMP's, both those within the composition of a detachment and independent ones, can have the following specializations in application to the surgical work that would be required following a nuclear burst: General surgical, traumatological, burn, jaw and face, neurosurgical, thoracoabdominal, anesthesiological, blood transfusion, ophthalmological, otorhinolaryngological, gynecological, urological, roentgenological, and radiological.

BSMP's that have been incorporated into a concrete specialized institution of the hospital base organize:

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Practical assistance in the problems of correctly organizing the work of receiving and sorting, surgical and dressing, and hospital departments;

efficient qualified diagnostic sorting;

proper special treatment of casualties of one profile or another.

Every team has its authorized outfit of medical stock. Surgical instruments, apparatus, medicines, and bandaging materials are stored in special packages. The expendables in these packages (medicines, bandaging materials, and so on) are intended to support the work of a team for 1 day.

Thus a BSMP that has been incorporated into the composition of a specialized hospital in the out-of-town zone supports it in its specialty by providing not only specialists but also equipment. The latter supplements the equipment of the out-of-town hospital and permits fulfillment of the tasks of a hospital base specialized institution.

On arriving at the out-of-town hospital, BSMP's are provided with working quarters, the lacking medical personnel, administrative and medical stock, hot and cold water, lighting, and so on. The arrangements are made by the senior physician of the specialized hospital.

Medical Sorting

Stage-by-stage therapy coupled with specific evacuation in relation to the nature of wounds would be impossible without medical sorting.

Medical sorting is needed to ensure the possibility for rendering timely aid to a maximum number of casualties for whom such aid could be life-saving.

Medical sorting is defined as distribution of wounded individuals and patients into groups requiring the same kinds of therapeutic-preventive and evacuation measures as determined from the medical indications, and the same volume of aid rendered in a given stage of medical evacuation. Medical sorting is based on diagnosis and prognosis. Sorting serves its purpose only in the event that it is performed quickly and skillfully and, what is most important, if it is adapted to a changing concrete medical situation.

The teaching on medical sorting was theoretically grounded and tested in practice by the great Russian surgeon N. I. Pirogov. In his works he deeply analyzed the problems of organizing aid to wounded individuals: "Whether or not all casualties without exception are provided first aid that cannot be delayed depends on administration, and not on medicine." Pirogov believes medical sorting to be one of the principal elements in wartime: "Having persuaded myself soon after my arrival in Sevastopol'

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that simple organization and order at the dressing station is much more important that purely medical activity, I made it my rule not to begin operating immediately after casualties are brought to these stations, but rather to begin sorting them immediately..., without being bogged down by time-consuming therapeutic procedures."

The teaching on casualty sorting developed by Pirogov passed the test of time and played an invaluable role in providing aid to wounded and patients in all subsequent wars.

From the moment it was introduced into practice, medical sorting has been constantly undergoing improvement: The necessary corrections are being made in accordance with the changing structure of medical losses, with achievements of medical science related to development of new resources and methods of diagnosis and therapy, and in connection with changes in the combat and medical situation stemming from the use of new forms of weapons.

Modern war in which weapons of mass destruction will be used will be characterized by simultaneous arisal of major centers of medical losses and, consequently, a dramatically expressed disproportion between the need for medical aid and the possibilities for rendering it. In these conditions correct and efficient organization of aid to victims acquires special significance.

Only a well organized system of aid to casualties and, most importantly, medical sorting will ensure timely implementation of therapeutic and preventive measures, and more-sensible use of medical manpower and resources depending on the structure of medical losses and the rate at which casualties arrive at the medical evacuation stages.

Medical sorting is performed right within the disaster center by personnel of medical teams. All casualties are divided into groups--those needing and those not needing immediate first medical aid. Measures that cannot be postponed would include stopping external bleeding and prevention of asphyxia. Aid directed at preventing shock and secondary infection of wounds is given on second priority.

After these measures are implemented the order of priority in evacuation of victims to the OPM is established. Severe casualties are evacuated on first priority, lying down in the most comfortable transportation available. Victims with traumas (burns) that are not severe leave the disaster center on their own, or they are conveyed out by motor transportation adapted for evacuation of seated casualties. Under otherwise equal conditions children are given the advantage in evacuation priority.

The OPM is the first stage of medical evacuation.

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One of the principal conditions for efficient work of an OPM's functional subdivisions is correct medical sorting. It begins at the distributing post (RP), which is set up by the OPM's receiving and sorting department nearby, at the approaches to the OPM. A paramedic or a nurse, one or two radiation supervisors, and one or two orderlies are assigned to work at the RP.

Casualties are subdivided into the following groups at the RP (Figure 1):

1) Infectious and psychoneurological patients--these are sent to the appropriate isolation wards;

2) victims contaminated by radioactive substances beyond permissible limits--these are sent to the department of partial personal cleansing and decontamination of clothing and footwear.

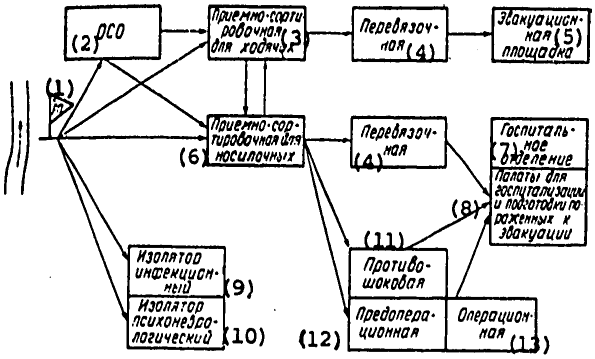

Figure 1. Basic Diagram of an OPM Deployed at the Focus of a Nuclear Burst

Key:

1. RP
2. Partial personal cleansing department
3. Receiving and sorting station for ambulatory casualties
4. Dressing station
5. Evacuation area
6. Receiving and sorting station for stretcher cases
7. Hospital department
8. Wards for hospitalization and preparation of casualties for evacuation
9. Infectious isolation ward
10. Psychoneurological isolation ward
11. Antishock ward
12. Preoperation room
13. Operating room

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All other casualties are divided into two groups--stretcher cases and ambulatory casualties, who are sent to the receiving and sorting department of the OPM.

Sometimes casualties exhibiting phenomena of asphyxia and those with unchecked bleeding and other life-threatening conditions can be sent from the RP directly to the antishock ward or the operating room, bypassing the receiving and sorting department. Persons with infectious and psychoneurological diseases are subject to swift evacuation from the OPM's isolation wards in separate transportation to appropriate specialized institutions in the out-of-town zone.

Following personal cleansing, casualties and patients contaminated by radioactive substances are sent, depending on condition, to the ambulatory or stretcher case stations of the receiving and sorting department. The receiving and sorting department is the main subdivision of the OPM in which medical sorting goes on. The latter is subdivided into local sorting, the objective of which is to determine the order in which casualties are to be sent to functional subdivisions of this medical stage, and sorting for evacuation and transportation, which has the objective of setting the priorities for sending wounded and patients to the next stage of medical evacuation.

Two sorting teams are assigned to this work in the receiving and sorting department, one for ambulatory casualties and the other for stretcher cases. The former works under the guidance of a general physician or a well trained paramedic, while the latter is headed by the most experienced physician-surgeon of the OPM. Each team consists of five persons--one physician (paramedic), two nurses, and two registrars. The teams are supplied with blank initial casualty accounting medical cards, which are the principal evacuation documents and the sole medical document issued prior to admission of casualties for hospital treatment, and sorting tags (figures 2, 3, 4). The team's equipment includes tourniquets, bandaging materials, splints, medicines, oxygen, and other items necessary for emergency aid. Medical sorting is performed by the flowline method. Together with the nurse and registrar, the physician approaches the casualty and determines the nature and severity of trauma and the forms and priority of aid required. If aid need not be rendered to the casualty at this stage, the issue of his evacuation is resolved. The appropriate tag is secured to the bandage or clothing of the wounded individual depending on the decision made. If the need exists, on instructions from the physician (paramedic) the nurse administers painkilling and cardiovascular agents, applies or straightens dressings, and so on. At this time the registrar fills in the necessary information on the medical card, and together with the nurse and registrar the physician begins working on the next casualty. This medical sorting method increases the throughput of the receiving and sorting department.

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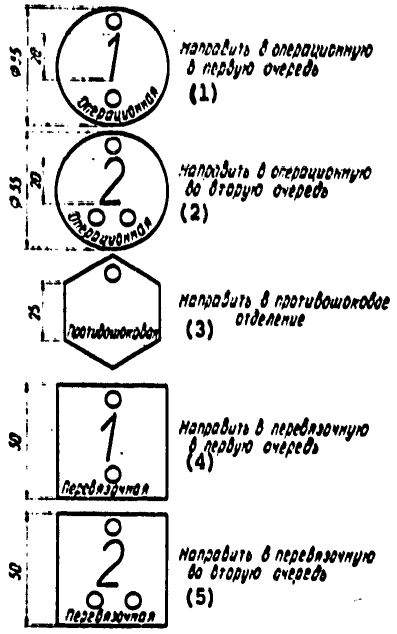

Figure 2. Sorting Tag Specimens

Key:

1. Send to operating room on first priority
2. Send to operating room on second priority
3. Send to antishock department
4. Send to dressing station on first priority
5. Send to dressing station on second priority

Children are much more intolerant of trauma and are more sensitive to blood loss.

It would be unsuitable to organize a separate flow of children, since this would complicate the work. It would be better to have the children undergo processing together with the parents, since the latter could communicate information about the trauma and other data necessary for resolution of the problems of rendering aid. Moreover parents can care for the children, which is also extremely important when large numbers of casualties are arriving.

During sorting it would be suitable to separate the casualties into the following five groups:

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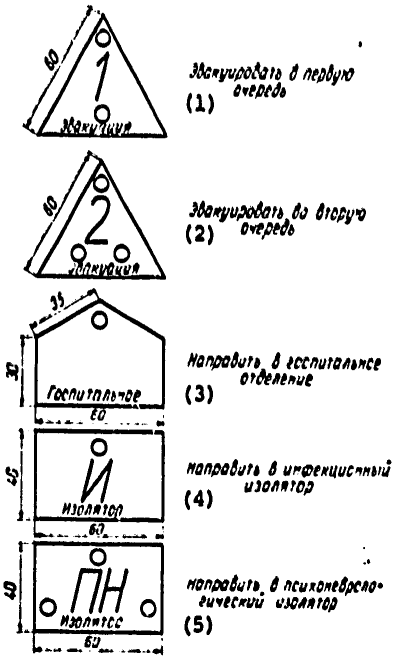

Figure 3. Sorting Tag Specimens

Key:

1. Evacuate on first priority
2. Evacuate on second priority
3. Send to hospital department
4. Send to infectious isolation ward
5. Send to psychoneurological isolation ward

1. Extremely severe traumas, including combined with damage to vitally important organs; burns exceeding 60 percent of the body surface (deep burns more than 50 percent). Victims are in a terminal or agonal state. First physician's aid fails to produce an effect.

2. Serious traumas of various locations, burns covering 20-60 percent of the body surface (deep burns not more than 45-50 percent). Prompt and adequate therapy may save the casualty's life. These casualties require first physician's aid on priority.

3. Traumas and burns of moderate severity--there is a potential for arisal of shock and complications. Victims require first physician's aid on second priority.

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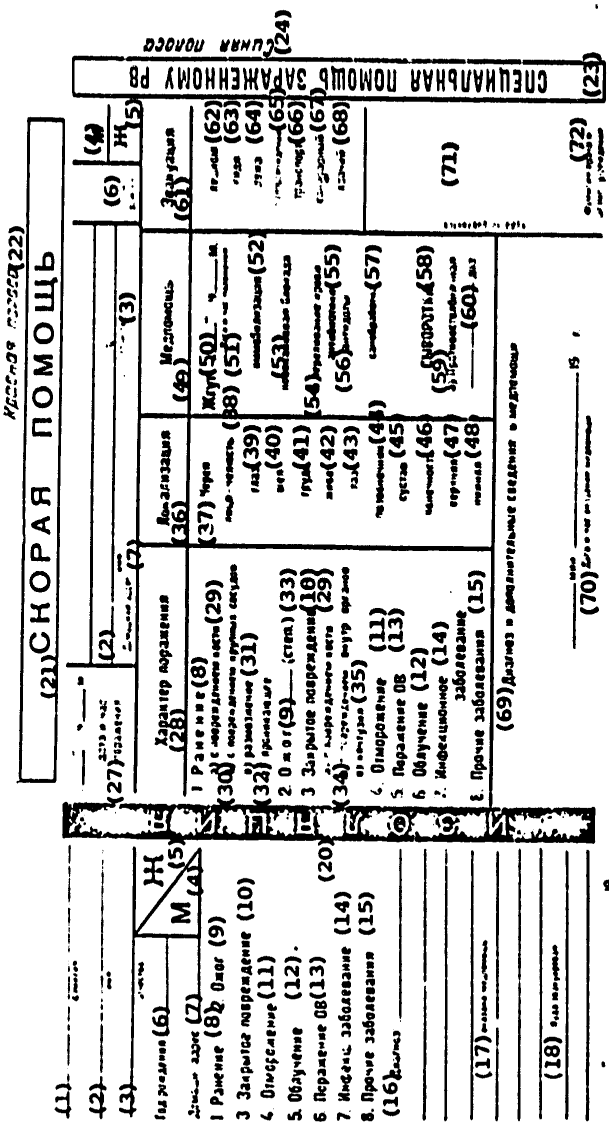

Figure 4. Civil Defense Medical Card [continued on following page]

Key:
1. Last name
2. First name
3. Patronymical
4. Male
5. Female
6. Year of birth
7. Home address
8. Wound
9. Burn
10. Open injury
11. Frostbite
12. Radiation
13. War gas injury
14. Infectious disease
15. Other diseases
16. Diagnosis
17. Medical aid rendered
18. Where evacuated to
19. Date card filled out
20. Isolation
21. Emergency aid
22. Red strip
23. Special aid to casualty contaminated by radioactive substances
24. Blue strip
25. Special aid to war gas casualty

[Key continued on following page]

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Figure 4. [continued]

Key [continued]:

26. Yellow strip
27. Date & hour of injury
28. Nature of injury
29. With bone damage
30. With damage to major vessels
31. Crushing
32. Penetrating
33. Degree
34. With damage to internal organs
35. Contusion
36. Location
37. Skull
38. Face-jaws
39. Eye
40. Neck
41. Chest
42. Abdomen
43. Pelvis
44. Spine
45. Joint
46. Limb
47. Upper
48. Lower
49. Medical aid
50. Tourniquet
51. Date & hour of application
52. Immobilization
53. Novocaine blockade
54. Blood transfusion
55. Antibiotics
56. Antidotes
57. Personal cleansing
58. Serums
59. Tetanus
60. Doses
61. Evacuation
62. On foot
63. Seated
64. Lying down
65. Under escort
66. Transportation
67. Medical
68. Other
69. Diagnosis & additional information on medical aid
70. Date & hour medical aid rendered
71. Destination
72. Physician's last name & seal of approval
73. Physician's special recommendations
74. Notes at following evacuation stages
75. Refined diagnosis, stage, & last name of sorting physician
76. Date & hour
77. Of arrival
78. Of departure
79. Medical aid rendered (indicate precisely what sort)
80. Where sent
81. Outcome
82. Therapeutic institution
83. Physician's last name

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4. Moderate or light traumas and burns. Victims are subject to treatment in specialized hospitals. They can undergo evacuation without first being given first physician's aid at the OMP.

5. Light traumas and burns. Victims require ambulatory treatment.

Thus this sorting provides answers to the three main questions: Which casualties do not need first physician's aid, which ones need it on the basis of vital indications, and in which cases is it desirable in support of further evacuation? When large numbers of casualties arrive with varying degrees of trauma it is extremely difficult to make a diagnosis and establish the prognosis: During the time of sorting the indications for removing dressings are not always present, it is not always possible to write up a detailed medical history, and there may not be time enough for a thorough examination. Under these conditions the diagnosis is made on the basis of a general examination and the most informative indices characterizing the form and degree of injury and the condition of the victim. In most cases there will not be enough time to make a refined diagnosis at the OPM.

Errors could be made during sorting, but they would be fewer in number if the sorting is done by an experienced physician having a good knowledge of wartime pathology.

In accordance with a decision made during the sorting, wounded and patients are distributed among the functional subdivisions of the OPM (Figure 5).

The ambulatory group of casualties is sent from the receiving and sorting department to:

The dressing station for preparation for evacuation;

the evacuation department;

the place of residence for outpatient treatment.

Stretcher cases are sent from the receiving and sorting department to: The antishock ward (department); the operating room; the dressing station; wards for hospitalization; the evacuation department.

Casualties in the first sorting group are sent to the hospital department. They are subjected to symptomatic therapy with the goal of easing their suffering. Such wounded (burn victims) are not subject to evacuation from the OPM.

Casualties in the second and third sorting groups require first physician's aid.

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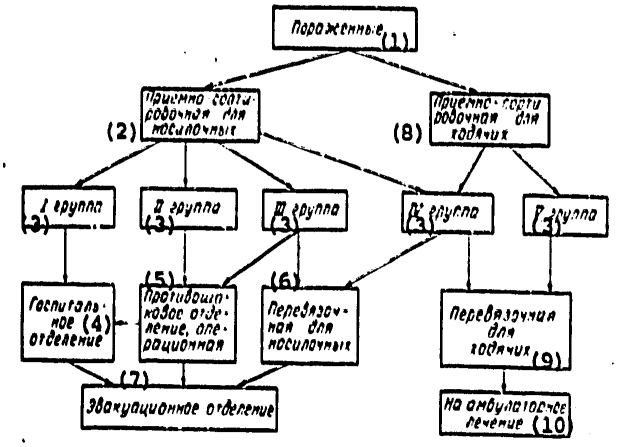

Figure 5. Formation of Sorting Groups at an OPM

Key:

1. Casualties
2. Receiving and sorting station for stretcher cases
3. Group
4. Hospital department
5. Antishock department, operating room
6. Dressing station for stretcher cases
7. Evacuation department
8. Receiving and sorting station for ambulatory casualties
9. Dressing station for ambulatory casualties
10. To outpatient treatment

It is important to note that sorting at an OPM is quite closely associated with the volume of medical care that can be rendered in the concrete situation. As the number of casualties increases the volume of aid must decrease, while as the flow of casualties decreases the volume of aid expands.

However, when increasing or decreasing the volume of medical aid, we must adhere to the maximum and minimum possible volumes of aid established for the given stage.

First of all aid must be given at an OPM on the basis of emergency indications. This aid includes:

Stoppage of external bleeding;

elimination of asphyxia;

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integrated antishock therapy and infusion of blood substitutes to treat high blood loss;

surgery on the basis of vital indications (tracheotomy, sealing of an open pneumothorax, puncture of the pleura in the presence valvular pneumothorax, amputation of a limb hanging by an unviable shred, and so on);

catheterization (puncture) of the urinary bladder;

administration of antibiotics and use of sulfanilamides and other preparations to prevent development of infection in the wound.

Measures that can be postponed include:

The complex of measures aimed at preventing shock in persons with severe traumas (burns);

necrotomy in the presence of circumferential burns;

replacement of dressing when wounds (burns) are contaminated by radioactive substances.

When the medical situation is favorable the full volume of first physician's aid is rendered, including all of the measures indicated above. This volume is reduced by foregoing the measures that could be postponed.

Casualties in the fourth and fifth sorting groups are given minimal aid even when the medical situation is favorable. In preparation for evacuation, dressings are applied or straightened, immobilization resources are applied for traveling, and painkilling, cardiovascular, antibacterial preparations, and so on are administered in accordance with the indications.

Sorting for evacuation is performed both in the OPM's receiving and sorting department and in the antishock, surgical, dressing, and hospital departments as the foreseen therapeutic measures are implemented and the question as to transportability of casualties is resolved. In this case we should consider the particular "leg" of evacuation (the distance from the OPM to the treating institutions), the availability and form of transportation, and the condition of the roads.

The OPM's evacuation department loads every vehicle with casualties of one particular profile, which facilitates their subsequent travel to specialized hospitals.

In accordance with the evacuation destinations, the casualties are moved from the OPM to the second stage of medical evacuation, to therapeutic institutions of the out-of-town zone (Figure 6).

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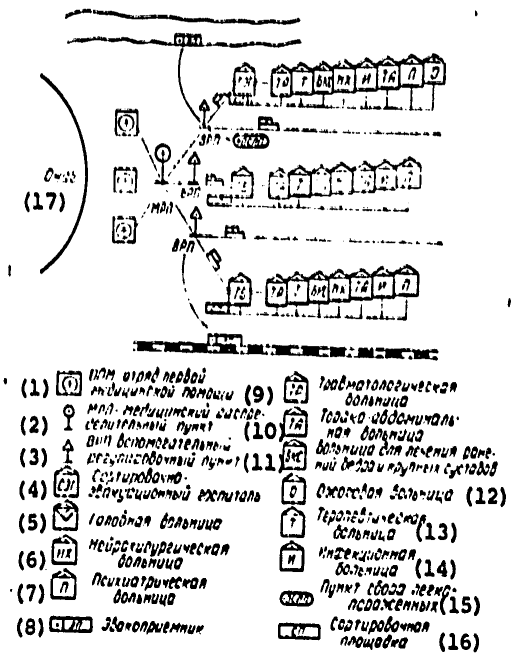

Figure 6. Evacuation of Casualties from the Center of a Nuclear Strike to Therapeutic Institutions of the Out-of-Town Zone

Key:

1. OPM--first medical aid detachment
2. MRP--medical distributing point
3. VRP--auxiliary control point
4. Sorting and evacuation hospital
5. Main hospital
6. Neurosurgical hospital
7. Psychiatric hospital
8. Evacuation and reception station
9. Traumatological hospital
10. Thoracoabdominal hospital
11. Hospital for treatment of wounds of thigh and large joints
12. Burn hospital
13. Therapeutic hospital
14. Infection hospital
15. Light casualty collection point
16. Sorting area
17. Focus

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A medical distributing point (MRP) is deployed along the principal evacuation routes by the SEG. It distributes the incoming transportation carrying casualties to the different hospital collection centers, thus loading them uniformly.

The main hospitals (GB) of the hospital collection centers deploy auxiliary distributing posts (VRP), the task of which is to control the flow of transportation and admit vehicles with casualties intended for the given collection center. In the sorting area of the SEG or GB, casualties are sorted while still in the vehicles when large numbers of them arrive. In this case casualties requiring emergency aid are revealed. They are sent to the receiving and sorting department of the GB or SEG, and then on the basis of medical sorting to the appropriate functional subunits of the given medical institution. Depending on the nature of the trauma and condition, the other group of casualties is evacuated to specialized hospitals of the hospital collection center.

On arriving in specialized therapeutic institutions of the out-of-town zone the casualties undergo internal sorting in the receiving and sorting department. Here the casualties are once again subdivided into groups requiring the same kinds of therapeutic-preventive measures, as determined from the medical indications, and the same volume of aid that is foreseen at the given therapeutic institution. Reduction of the volume of medical aid rendered at the OPM would require corresponding expansion of the assistance given to casualties in therapeutic institutions of the out-of-town zone.

Thus sorting is a continuous process which goes on at each stage of medical evacuation in accordance with the tasks of the stage, the volume of aid established for it, the medical situation, and the qualifications of the medical personnel.

Sorting begins from the moment first medical aid is rendered, and it ends in the specialized therapeutic institutions.

It follows from all of this that when there are large numbers of casualties, sorting is one of the decisive factors defining the success of the system for stage-by-stage therapy coupled with specific evacuation depending on nature of wounds.

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CHAPTER 2

PREVENTION AND TREATMENT OF TRAUMATIC SHOCK

Traumatic shock is a vitally dangerous complication of severe injuries, in the presence of which regulation of the functions of vitally important systems and organs becomes disturbed and then constantly worsens, in connection with which severe circulatory disturbances and tissue circulatory hypoxia develop, and metabolism suffers. This definition is not exhaustive from the point of view of the pathological physiology of the process, nor does it claim to shed any light on the general biological significance of the shock reaction, but it does sufficiently reflect the main things--the etiology, essence, and outcome of traumatic shock, knowledge of which is necessary for a correct understanding of the clinical pattern, prevention, and treatment of this condition in different stages of civil defense medical evacuation. There are two phases in the development of shock: Erectile--the arousal phase, and torpid--the inhibition phase. The torpid phase is subdivided into three degrees depending on severity of clinical manifestations: Degree I--mild shock, degree II--severe shock, and degree III--terminal condition.

By subdividing the torpid phase of shock into three degrees we clearly delineate the principal clinical stages in development of the process, define their symptomatology, and promote creation of the appropriate recommendations for stage-by-stage treatment.

Clinical Pattern of Traumatic Shock

Erectile Phase

If shock is not combined with radiation injury, the erectile phase lasts several minutes. It is typified by general restless and mental and vocal arousal. The victim cannot properly evaluate the severity of his condition. The pulse is normal or fast. Arterial pressure is normal or somewhat high. A combination of arousal and severe trauma is the grounds for diagnosing the erectile phase of shock. The more dramatically pronounced the arousal, the more serious the torpid phase of shock.

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Torpid Phase

Degree I--mild shock: The patient remains conscious and he answers questions correctly, but he is reluctant to come into contact. The skin and visible mucous membranes are pale. Body temperature is normal or somewhat low. The pupils are of normal size, and they react to light. The pulse is rhythmical, sometimes accelerated to 100-110 beats per minute. Heart sounds are dull. Systolic pressure is 110-70 mm Hg, and diastolic pressure is 65-55 mm Hg. Breathing is uniform, deep, and sometimes rapid. All reflexes are mildly subdued. The volume of circulating blood is down by 30-35 percent.

Degree II--severe shock: The condition is serious. The victim is conscious but out of touch with surroundings and his injury. Reactions to external stimuli are sluggish and slow. The pupils are narrow, and they react weakly to light. All reflexes are subdued. Tissues in the area of injury exhibit signs of (giposteziya) [hyposthesia?]. The skin is pale with a greyish hue, and cold to the touch; body temperature is low. The pulse is rapid and weak, sometimes noticeable only with major vessels; heart sounds are dull. Systolic pressure is below 70 mm Hg, and diastolic pressure is below 30-40 mm Hg or undeterminable with a sphygmamometer. The volume of circulating blood decreases by 45 percent and more. Breathing is superficial, fast, and nonuniform in depth. Circulatory hypoxia is present, and all forms of metabolism are disturbed.

Degree III--terminal condition: The victim is unconscious. The skin is pale, of a greyish hue, cold, and covered with cold sticky sweat. The pupils are dilated, and they react poorly to light or not at all. Arterial pressure is undeterminable, and no pulse can be felt. Breathing is superficial and irregular. Convulsions occur.

In the presence of combined radiation injuries of mild and moderate severity the period of initial reactions coincides in time with development of traumatic shock. In this case we observe mutual aggravation of two pathological processes; the clinical course of shock changes noticeably, and distortion of the body's reactions to some therapeutic measures may be observed. The erectile phase of shock lasts not in the usual minutes but rather for an hour and more. But this is not a symptom of well-being, since following the protracted erectile phase arterial pressure drops quickly and severe traumatic shock develops in short time.

First Medical Aid

In the center of mass destruction sorting following the "alive-dead" principle is performed by medical teams. For this purpose they must: 1) Determine whether or not the victim is conscious; 2) take his pulse with the radial artery and, when the upper limbs are injured, with the femoral or carotid arteries and compare it with the pulse of the examiner; 3) establish whether or not the victim is breathing; 4) determine if the pupils contract in response to light, and note their size.

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In the absence of pulse, respiration and consciousness, and when the pupils are dilated and do not react to light, the victim is pronounced dead. If two out of three signs (consciousness, pulse, respiration) are found to be negative while the pupils react to light, the victim is said to be alive. After rendering first aid he is evacuated to an OPM. Shock prevention must begin where the victim is found. It involves careful application of aseptic dressings to the wound and burn surfaces, application of a tourniquet or pressure bandage to stop bleeding, immobilization of an injured limb using an improvised or traveling splint, prevention of the victim's cooling, and evacuation in the most comfortable transportation.

Shock prevention with pharmacological agents involves the use of analgesics, preparations of the phenothiazine series, antihistamine preparations, and so-called antihypoxants. The latter dramatically reduce the body's reactions to all trauma, including recurrent. Their use prevents traumatic shock even in the presence of very severe traumas.

All severe casualties with readily determinable pulse must be given a tablet containing promedol (0.1 gm), aminazin (0.05 gm), and ditizol (0.1 gm).

Victims with a poor pulse--that is, those who may have gone into shock, must receive a tablet containing dimedrol (0.1 gm), promedol (0.1 gm), ditizol (0.1 gm), and a tranquilizer. Aminazin is contraindicated in relation to such casualties. Vitamins also increase the body's resistance to trauma and shock. All severely wounded persons must receive a tablet containing a vitamin complex (C--500 mg, B_1--10 mg, B_6--15 mg, nicotinamide--50 mg).

Treatment of Traumatic Shock

Treatment of victims with traumatic shock begins in an OPM.

An antishock team is organized out of personnel from the surgical and dressing department and the hospital department and furnished with specialized wards to treat traumatic shock. The composition of the team must be constant, and the responsibilities of the personnel must be clearly spelled out: Every member of the team must assimilate the antishock therapy methods within the limits of his responsibilities, acquire the necessary skills, and study the antishock kit and apparatus.

The following must be done in the receiving and sorting department to diagnose shock: Evaluate the overall condition of the victim, his ability to orient himself in the surrounding situation, the adequacy of reactions to external stimuli, and the extent of his consciousness; determine the color of skin surfaces and visible mucous membranes; note the size of the pupils, their uniformity, and their reaction to light; check the frequency, rhythmicity, and strength of the pulse; measure arterial pressure; gain a general impression of the nature of injuries.

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A tentative diagnosis of shock is made on the basis of the obtained data, and its degree is indicated. When the victim is in the erectile phase of shock and in degree I shock he remains in the receiving department, where antishock therapy is performed. Victims in degree II and III shock are placed in the antishock ward. Their pulse is thoroughly evaluated once again, body temperature is measured, tendon and abdominal reflexes and muscle tone are checked, injuries are diagnosed by the routine procedures, and hourly diuresis is determined.

Table 1 gives a basic idea of systolic pressure indices depending on age and the severity of shock.

Table 1. Systolic Pressure Indices in the Presence of Traumatic Shock Depending on Age

Возраст в годах (1)	Систолическое давление, мм рт. ст. (2)			
	норма (3)	при легком шоке (4)	при тяжелом шоке (5)	в терминальном состоянии (6)
1—5	80—90	65—60	45—40	Артериальное (9) давление не определяется
6—10	90—100	75—65	50—45	
11—19	100—110	85—75	60—50	То же (10)
20—60	120—130	110—70	(8) Ниже 70	» »
60—75	130—160	120—115	100—90	» »
Старше (7)				

Key:

1. Age, years
2. Systolic pressure, mm Hg
3. Normal
4. In presence of mild shock
5. In presence of severe shock
6. In terminal condition
7. Older
8. Below
9. Arterial pressure undeterminable
10. As above

Treatment of Patients in the Erectile Phase of Shock

Dressings must be checked and, if necessary, straightened and bandaged down. Improvised splints should be replaced by standard ones to the extent possible, tourniquets should be removed, and external bleeding should be stopped. Injured areas must be thoroughly anesthetized by means of local or intraosteal anesthesia, injection of novocaine into a hematoma in the presence of fractures, or vagosympathetic, paranephral, or (futlyarnaya) blockade according to A. V. Vishnevskiy's method, Shkol'nikov's blockade in the presence of pelvic fractures, and so on. Intramuscular injections should be given of 1 percent aminazin solution (1 gm), 2 percent promedol solution (2 gm), 2 percent dimedrol solution (1 gm), and 1 percent ditizol solution (10 gm). It would be desirable to infuse, dropwise intravenously, 250 ml blood substitute supplemented with vitamin solutions: 1 percent C--

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--10 ml, 6 percent B_1--2 ml, 6 percent B_6--1 ml, and a 0.5 percent novocaine solution--0.6 ml per kilogram body weight of the victim.

Treatment of Mild Shock

Maximum rest must be afforded to the patient and injured tissues, bleeding should be stoppped, and shock-producing stimuli must be excluded. Two hundred fifty millilitres of a fluid of the following composition are infused streamwise into the ulnar vein at a pressure of 180-200 mm Hg: Blood substitute--100 ml, 40 percent glucose solution or 5 percent sodium chloride solution--100 ml, insulin--3-4 units (if glucose is infused), vitamin solutions: 6 percent B_1--2 ml, 6 percent B_6--1 ml, 1 percent C--50 ml, 1 percent norepinephrine solution--0.5 ml, 0.06 percent corglycon-- 1 ml. If arterial pressure rises, the skin reddens, the pulse slows down, and the victim's overall condition improves, we can assume that shock will not subsequently become more severe. In cases where arterial pressure recovers slowly and does not return to normal after transfusion is completed, another dose of the same fluid must be infused intravenously. After arterial pressure returns to normal (100-120 mm Hg) the resulting effect is stabilized by prolonged dropwise intravenous infusion of 0.5 percent novocaine solution at a dose of 0.6 ml per kilogram of body weight of the victim.

In the simplified variant of mild shock treatment we can use a fluid consisting of equal parts of blood substitute and 40 percent glucose solution, or blood substitute and 5 percent sodium chloride solution supplemented with norepinephrine (0.5 ml 1 percent solution per 250 ml fluid).

Treatment of Severe Shock

Begin with intravenous streamwise infusion of a mixture (500 ml) containing blood substitute (200 ml), 40 percent glucose solution (200 ml), insulin (6-8 units), a complex of vitamin solutions (1 percent C--100 ml, 6 percent B_1--2 ml, 6 percent B_6--2 ml, 1 percent PP--1 ml), 0.06 percent corglycon--1 ml, and 1 percent norepinephrine--1 ml. Such "test therapy" should reveal the body's reaction to infusional antishock therapy and facilitate prognosis of the outcome.

When the result is positive--arterial pressure rises noticeably after the "test"--we can count on quickly eliminating the casualty's severe state. Gains should be consolidated and developed with the use of the entire complex of antishock measures. Blood substitutes supplemented only with norepinephrine (1 ml 1 percent solution per 500 ml blood substitute) should be infused intravenously until arterial pressure returns to normal.

Administration of fluids containing morphine, alcohol, novocaine, and aminazin is contraindicated during this period, since they keep arterial pressure from rising.

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In order to prevent and control metabolic acidosis, 200-250 ml 4-5 percent sodium bicarbonate solution is infused dropwise intravenously, while to improve kidney activity mannitol is infused streamwise intravenously at a dose of 1-1.5 gm per kilogram body weight. Oxygen inhalation is indicated.

When arterial pressure reaches 100-120 mm Hg it is stabilized by dropwise intravenous infusion of 0.6 ml/kg 0.5 percent novocaine solution. As a result circulation stabilizes in 2-3 hours and an adequate blood supply is ensured to tissues and organs. The significance of artificial stabilization grows when isotonic or hypertonic solutions of electrolytes and glucose must be used rather than blood substitutes to relieve shock; in this case it would be easier to raise arterial pressure than to maintain it at a high level.

If streamwise infusion of a "test dose" does not noticeably increase arterial pressure in children and senile persons, intermittent intraarterial infusion of blood substitute under pressure is employed. The ulnar or posterior tibial artery is exposed under local anesthesia, observing aseptic conditions: The artery is punctured, and an intraarterial injection system filled with blood substitute is connected; a Pean clamp is applied to the rubber tube below the glass control tube, 15-20 cm from the needle. A pressure of 200-250 mm Hg is created in the ampule or standard cup; if the ampule is substituted by a Bobrov apparatus the pressure in it is increased to 260-280 mm Hg. The rubber tube is pressed shut with a Pean clamp 30 times per minute.

Intraarterial injection is halted when a tendency toward further rise in arterial pressure becomes distinct. Intravenous transfusion of blood substitute supplemented with vitamins, cardiac agents, and antihistamine preparations continues until arterial pressure normalizes, after which measures are taken to achieve "artificial stabilization," as described above.

If intermittent intraarterial injection of 500 ml blood substitute to a victim in a state of shock does not produce a noticeable rise in arterial pressure (15-20 mm Hg), further treatment should be recognized as unpromising.

When there is not enough blood substitute to raise arterial pressure, a 5 percent glucose solution, physiological solution, hydrolysin, or anti-shock solutions could be used. If blood loss is low, arterial pressure can be normalized in 10-12 minutes. In order to keep it from dropping, "artificial stabilization" must be achieved immediately by infusing 0.6 ml/kg 0.5 percent novocaine solution into a vein, or injecting 1 ml 1 percent morphine solution subcutaneously. In these cases the favorable effect lasts about 30 minutes.

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Surgery is performed in the presence of shock only on the basis of vital indications, and in minimum volume--to stop blood loss, to restore breathing, and in the presence of increasing pneumothorax.

When the casualty is old or senile, treatment is limited to halting external blood loss by application of clamps to vessels, intubation, and puncture of the rib cage in the presence of increasing pneumothorax: Surgery of any greater complexity is 100 percent lethal.

Surgery is employed to halt bleeding despite the fact that arterial pressure cannot be increased above 70 mm Hg. The operation is performed with superficial anesthesia employing a ganglionic blockade without achieving hypotension: Intravenous dropwise infusion of norepinephrine is started (1 ml per 250 ml physiological solution), and then 50-60 mg hexonium and 80-100 mg pentamin is administered into the rubber tube with a syringe. The rate of introduction of the pressor agent is regulated in such a way that pressure would remain at 100-110 mm Hg. The surgeon can now operate for 2 hours without additional administration of gangliolytics. Arterial pressure remains at a rather high level not only during the operation but also sometimes after it, if hemorrhaging is controlled and lost blood is replenished. Insensitivity of vessels to pressor amines is a contraindication to the use of this method.

Treatment is not performed in a terminal state. Casualties in this state are sent to the hospital department, where symptomatic therapy is provided to them. When "test therapy" produces negative results--arterial pressure not only fails to increase but even decreases sometimes--the volume of aid and the subsequent course of antishock therapy depend on the tactical and medical situation: When conditions are favorable 500 ml blood substitute and norepinephrine (1:500) is injected into the artery, and if arterial pressure does not rise as a result, antishock therapy is halted and only symptomatic therapy is provided; in an unfavorable situation antishock measures are terminated after failure of the "test therapy."

Absence of a positive result from antishock therapy may be associated with the casualty's lengthy presence in a state of shock or with extensive damage to organs of the thoracic and abdominal cavities (cardiac contusion, ruptures of the lungs, crushing of the liver, hemorrhaging in the adrenal glands, extensive retroperitoneal hemorrhaging, intraperitoneal hemorrhaging), severe brain damage, and so on. It should be considered that even in clinical conditions such patients remain in shock for a day and more, mortality rising to 80 percent and above.

The perspectiveness of antishock therapy and, consequently, the prognosis of the outcome depend in all evacuation stages on the severity of injuries, the time since shock began to develop, the victim's age, the body's reactions to therapeutic measures, and the special working conditions of the given stage.

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Thus a prognosis based on clinical data can be formulated at the OPM in the form of the following premises:

In relation to middle-aged victims when it is possible to implement an expanded volume of measures to treat severe shock, antishock therapy must continue until "test therapy" supplemented by intraarterial injection of 500 ml blood substitute and implementation of other measures does not lead to normalization of arterial pressure, or until it is accompanied by recurrent declines in pressure; when the situation requires that the volume of aid be reduced, antishock therapy is terminated after failure of "test therapy";

in relation to old and senile persons when the full volume of aid can be provided, specific therapy must continue until "test therapy" and intra-arterial injection of blood substitutes for 1 hour do not produce positive results; when the volume of aid must be reduced, specific therapy is halted following failure of "test therapy" and intraarterial injection of 500 ml blood substitute;

antishock therapy must be provided to children until the onset of agonia.

Victims who recover from shock are subject to evacuation to institutions in the out-of-town zone on first priority.

When arterial pressure is unstable, evacuation is permitted only as an exception in connection with an unfavorable practical tactical and medical situation, when complex surgery would be required to stabilize arterial pressure and preserve life.

Antishock therapy is provided in the out-of-town zone's hospital collection center by the main hospital, where an antishock department is deployed. This department is responsible for: Treatment of all degrees of shock in victims delivered from OPM's, and completion of the treatment of persons from OPM's exhibiting unstable arterial pressure or symptoms of shock "aggravated" during transportation; clarification of the diagnosis, and treatment of traumatic shock in cases of combined injuries.

The scheme of antishock therapy followed in the main hospital consists of the same elements as those in therapy provided by the OPM, but it does have some unique features connected with better equipment availability and other conditions of work in this stage. In addition to blood substitute, preserved blood is used, which has special significance to the treatment of victims suffering a combination of shock and massive blood loss (Table 2), as well as to treatment of shock in children and senile persons.

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Table 2. Determination of Amount of Blood Loss

Количество излившейся крови, мл (1)	Удельный вес (2)	Гемоглобин, единицы (3)	Гематокрит, % (4)
До 500 (5)	1057—1054	65—62	44—40
» 1000	1053—1050	61—50	38—32
» 1500	1049—1044	53—38	30—23
Более 1500 (6)	1044	43	23

Key:

1. Amount blood lost, ml
2. Specific weight
3. Hemoglobin, units
4. Hematocrit, %
5. Up to
6. More than

The possibility afforded for treating shock until the final outcome without a consideration for the time element provides an opportunity for broader use of the most effective methods for introducing blood (intraarterial injection by the continuous and fractional methods, prolonged dropwise intravenous infusion); organization of direct blood transfusion is possible.

Hormone therapy can be provided to old and senile victims in a state of shock from the moment of their arrival (intravenous, dropwise infusion of 50-80 units ACTH and 100-125 mg hydrocortisone); subsequent hormone therapy is provided in accordance with the treatment scheme. To achieve artificial stabilization of arterial pressure, in addition to 0.5 percent novocaine solution we can use superficial anesthesia with nitrous oxide (1:1), muscle relaxants (ditiline--80-100 mg, or deplasin--100-200 mg), and ACTH. These substances, which differ in their mechanism of action on vascular tone, are functional synergists in this case.

Specific Features of the Diagnosis and Treatment of Shock in the Presence of Combined Injuries

The most difficult situations associated with shock are observed when cerebrocranial trauma is combined with severe multiple injuries to the limbs. Cerebrocranial trauma itself is very rarely accompanied by shock, and as a rule it expresses itself as the concussion, cerebral compression, and cerebrocranial coma syndromes. When combined with trauma to the limbs, which is often complicated by shock, the symptoms of shock and cerebrocranial trauma superimpose over one another, often cancelling each other out. In particular the cardinal symptoms of shock--hypotension and tachycardia--are not always revealed in the presence of cerebral concussion and compression. Diagnosis of the combination of cerebrocranial coma and shock is especially difficult. Test intraarterial blood injection is the only means helpful to reaching a correct decision. If in this case arterial pressure rises and consciousness does not return, coma or its combination with shock would be suspected; if pressure gradually increases

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and the patient returns to consciousness, a diagnosis of traumatic shock becomes doubtless. If a diagnosis of traumatic shock is made in the presence of damage to the skull and brain, the full volume of antishock therapy is provided. When extensive injuries to body and limbs are combined with severe trauma of the rib cage, it is sometimes difficult to establish the principal cause of hypotension. It may be shock, or ventilational hypoxia on the background of respiratory insufficiency (paradoxical movement of portions of the thoracic wall during breathing in the presence of multiple rib fractures, contusions and ruptures of the lungs, tension hemopneumothorax coupled with displacement of the mediastinum), cardiac contusion, mediastinal emphysema, and any combinations of these injuries.

By extending injured portions of the thoracic wall beyond the sternum and rib in the presence of paradoxical movements, we can increase the pulmonary ventilation volume, reduce tissue hypoxia, and normalize arterial pressure. If this does not happen, traumatic shock is diagnosed and the appropriate therapy is provided.

A special chapter is devoted to diagnosis and treatment of injuries to organs of the thoracic cavity. At this point we need simply note that it is difficult to diagnose and treat combinations of shock and cardiac contusion.

The principal symptom of cardiac contusion is compensatory tachycardia, reaching up to 140-160 per minute. It often combines with low arterial pressure and, what is especially important, with very low pulse pressure, dropping down to 20 mm Hg. Tachycardia accompanying cardiac contusion is unique in its stability: It cannot be relieved by conventional resources.

Instability of arterial pressure with a tendency toward decline despite the therapy conducted is an important sign, which manifests itself sometimes in the first day and more frequently on the second and third days. In half of the cases cardiac contusions are observed to be accompanied by dyspnea and cyanosis or paling of the face depending on which symptoms dominate--those of shock or those of compression of the rib cage. More often the cardiac rhythm remains normal if the contusion does not affect the septum. When the latter is injured, arrhythmia arises.

One degree or another of myocardial hypoxia is observed on the EKG in the zone of contusion, and changes in conduction are observed in some cases; these signs combine with pronounced sinus tachycardia. Even with a suspicion of cardiac contusion treatment of traumatic shock must proceed differently from normal. In each case the scheme of shock therapy is adjusted individually.

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The patient must be placed under controlled breathing. Intraarterial transfusion of blood of the same group, even if considerable blood loss had occurred, must be conducted cautiously, in fractional doses just until the blood loss is replenished, and not more. In this case recovery of arterial pressure to normal level is not a goal in and of itself. If systolic pressure does not drop below 80-90 mm Hg, it would be better not to perform blood transfusion.

Administration of fluids must be stricly limited, and it must be performed dropwise at a rate of 40 drops per minute. It would be better to use the low molecular weight compounds gelatinol or dextran. It would be useful to add glucose and insulin, vitamins B_1 and B_6, ascorbic acid, and 10 percent sodium chloride solution (20 ml) and, in the presence of increasing acidosis, 4 percent sodium bicarbonate solution (100 ml) to the fluid. The total quantity of fluid administered per day must not exceed 1.5 liters.

In the presence of tachycardia and when arrhythmia taking the form of flutter, paroxysmal tachycardia, and extrasystole arises, use of ganglionic blocking agents is indicated (inderal 3 to 4 times a day, 20 mg beneath the tongue or 1 ml intramuscularly, and gradually intravenously). We can also use pentamin (50-80 mg) on the background of intravenous dropwise infusion of sympathomimetic amines--mezaton or norepinephrine. Prescription of cardiovascular agents--camphor oil, caffeine, cordiamine--is mandatory.

It would be better to refrain from using cardiac glycosides in the first hours, if phenomena of acute cardiac insufficiency (cardiac asthma, pulmonary edema) are absent. Subsequently, cardiac glycosides are used in accordance with the indications. When cardiac contusion is combined with severe shock, use of steroid hormones in the glycocorticoid group (prednisolone, desoxycorticosterone) in combination with preparations having anabolic action (nerobol, methylandrostenediol) wouldbe indicated.

In the first 2-3 days the patient must not receive food or fluids *per os*. Throughout the entire time of treatment the patient is subjected to intense oxygen therapy, taking the form of inhalation of an air-oxygen mixture.

Operations necessary by nature of the trauma can be performed in the presence of a cardiac contusion only on the basis of vital indications; proper anesthesiological support must be provided, and the surgery must be kept at a minimum volume.

Shock in the presence of injury to organs of the peritoneal cavity and pelvic fractures is aggravated by intraperitoneal hemorrhaging or bleeding into the peritoneal tissue, in connection with which pulse and arterial pressure are unstable and difficult to stabilize, despite therapy. Blood loss and shock aggravate one another mutually.

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Specific Features of the Course and Treatment of Shock Among Elderly and Senile Patients

Extremely severe shock, difficulties in treatment, and high mortality rate are typical. Accompanying damage to the skull and to organs of the thoracic and peritoneal cavities are often not diagnosed in time.

The degree of shock can be determined only approximately on the basis of the arterial pressure. Patients with hypertension may be suffering severe shock even when the arterial pressure is 120-130 mm Hg, but in this case the pulse does not correspond to the pressure level: It becomes fast and irregular; the volume of circulating blood decreases dramatically, and breathing disturbances are often observed. The reaction to the usual antishock measures is subdued, and sometimes it is absent.

Intermittent intraarterial and dropwise intravenous transfusion of freshly citrated oxygenated blood together with vitamins C, B_1, B_6, and B_{12}, 50-80 units of ACTH, and 100-125 ml hydrocortisone would be suitable, monitoring venous pressure all the while.

If arterial pressure does not rise, 80-100 mg pentamin or 50-60 mg hexonium must be administered and pressure must be stabilized by dropwise infusion of 1 °/oo norepinephrine solution at 120-130 mm Hg. The patient should be subjected to auxiliary or artificial lung ventilation, and 200 ml 4-5 percent sodium bicarbonate and 1-1.5 gm/kg mannitol must be introduced into the vein. After arterial pressure normalizes, 0.6 ml/kg 0.5 percent novocaine solution is infused dropwise intravenously. Surgery performed prior to relief of shock results in almost 100 percent mortality, for which reason application of clamps to stop external bleeding is all that is permissible, assuming that exposing the vessel would not mean extensive probing of the wound. Surgery made necessary by the nature of injury can be performed 8-10 hours after the patient comes out of shock.

If it is found that surgery is made necessary by the nature of the injury before the victim comes out of shock, and when energetic antishock treatment does not produce an effect in an hour, antishock therapy should be halted, and treatment should be limited to administration of painkillers.

Specific Features of the Course and Treatment of Shock Among Children

Shock develops quickly in children, reaching its greatest severity in short time (degree II and III). At the same time even severe, highly stable functional disturbances in organs and systems are reversible in most cases.

The complex of therapeutic measures is basically the same as that used with adults, but it does have its unique features. Immediate streamwise injection of blood into the vein and even into the artery does not always produce a positive result. The best choice is intermittent intraarterial injection, in which case the pressure in the ampule must exceed the child's normal

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arterial pressure by 60-80 percent; every time arterial pressure increases by 5 mm Hg, a break should be taken for the time during which the attained level remains stable; when venous pressure rises quickly, injection is halted. Intravenous transfusion of blood and fluids after raising arterial pressure to the critical level should only make use of the dropwise method , with venous pressure being monitored.

Medicines--vasopressors, hormones, vitamins, and so on--are dosed in relation to the child's age:

Up to 1 year	1/24-1/12 of adult dose	
1 year	1/12	" "
2 years	1/8	" "
4 years	1/6	" "
6 years	1/4	" "
Up to 7 years	1/3	" "
14 years	1/2	" "

Artificial stabilization of arterial pressure is achieved by intravenous administration of 0.5 ml/kg 0.5 percent novocaine solution.

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CHAPTER 3

THE PROLONGED COMPRESSION SYNDROME

Prolonged compression (the "crush syndrome" using the terminology of foreign authors) is a unique form of mechanical injury to soft tissues often characterized by a severe clinical course and high mortality.

Etiology and pathogenesis: The principal etiological factor of the malady is prolonged pressure of objects upon soft tissues of the limbs, head, and torso.

During the time of action of the traumatizing agent and in the subsequent period, various disturbances develop in the victim's body, which go a long way in predetermining the subsequent course. Immediately after the beginning of traumatization the patient experiences intense pain and motor arousal. The erectile phase of compressional shock may last from several minutes to 1-1.5 hours. Experimental arterial pressure remains relatively high in the course of 2-3 days of traumatization, and it does not drop below 90 mm Hg. As a rule the victims exhibit numbing of the traumatized portion of the body and portion of the limb above the distal point of injury. It was established in 1972 (R. Ya. Gershtenkern, T. M. Chekanina) that so-called adaptation to pain is elicited by blockage of pulses in cerebrospinal ganglia.

Experimental data indicate that skin, muscles, and their nervous conductors are highly resistant to pressure and ischemia. Thin (slow-conducting) nerve fibers transmitting information to the central nervous system are especially stable.

Soon after the cause of crushing is eliminated and circulation is restored in the traumatized portions of the body, the activity of surviving slow nerve fibers revives and the obstacle to conduction in cerebrospinal ganglia is removed (R. Ya. Gershtenkern, T. M. Chekanina). A number of electrolytes (potassium, phosphorus, magnesium, ammonia) enter the bloodstream from the traumatized area, disturbing nervous and endocrine regulation. Specific antigens having toxic properties, formed during the time of compression,

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coexist in blood together with the usual metabolites (R. Ya. Gershtenkern, V. G. Deynega, 1964).

Following decompression, pathological neurogenic influences undergo dramatic intensification, and toxemia simultaneously acquires a major role, proceeding on the background of disturbances in function of the nervous system, kidneys, and liver, hypoxia, and oligemia. After being recovered from rubble, casualties are in a unique state of postcompressional shock pathogenically associated with nervous reflex and toxemic factors, and plasma loss.

The pathogenesis of the toxemic period (the intermediate period, using M. I. Kuzin's terminology) is characterized by retention of intermediate metabolites, electrolytes (potassium, phosphorus, magnesium), and water by the body as a result of acute renal insufficiency and disturbance of the detoxification activity of the liver and the regulatory function of the central nervous system on the background of persisting dystrophic and destructive changes in traumatized tissues, from which metabolites constantly originate. It may take a long time for muscular dystrophy to transform into waxy necrosis (10-15 days). The period of toxemia lasts until the epithelium of renal convoluted tubules begins regeneration and the function of the tubules recovers. Together with a decrease in osmotic resistance of erythrocytes, disturbance in the erythropoietic function of bone marrow leads to anemia.

Pathological anatomy: There are abrasions or bruises on the skin in the area of compression, and subcutaneous and intramuscular connective tissue is edematous. Edema often spreads to adjacent areas. Hemorrhaging can be observed in muscles and beneath the skin. Muscles have a clayey appearance, they are edemic, and on occasion they are dry. Internal organs are plethoric. Multiple hemorrhaging and erosion is encountered in the antral division of the stomach, the duodenum, and the terminal part of the iliac division. Gangrene can be found in very severe cases in part of the appendix or the sigmoid flexure. Examination of the kidneys reveals ischemia of the cortical layer and plethora of the medullary layer, protein dystrophy, necrosis of the epithelium of convoluted tubules, predominantly distal, and constriction of the tubules due to edema of connective tissue. Some of the tubules may be plugged with proteinaceous matter (sloughed epithelium, fibrin, myoglobin, and so on). Small spotty necroses are encountered in the liver, myocardium, spleen, and brain.

Clinical pattern: Intense pains in the crushed portion of the body last for several minutes to 2 hours. During this time the victim is aroused, pleads for help, and bites his hands and lips from pain. Loss of consciousness does not occur as a rule. During the remaining time of his presence in the rubble the victim is relatively calm, signals his presence, replies to questions, and can assist in his own rescue. Weakness, thirst, and dryness of the mouth can be noticed. When present for a very long time in the rubble, the victim may periodically fall into a drowsy state. After rescue, many victims exhibit arousal (talkativeness, inadequate

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reactions to the surroundings) and chills. If on being rescued a tourniquet is applied to a traumatized limb, chills arise following its removal.

When the crushing agent is removed and if crushing had persisted for a long time, collapse may occur, followed by a swift lethal outcome.

Three periods can be distinguished in the clinical pattern of the syndrome--early (postcompressional shock), intermediate (toxemia), and late (complications). The classification proposed by M. I. Kuzin (1959) for severity of the prolonged crushing syndrome is the most acceptable: Extremely severe form (develops when both lower limbs are crushed for 8 hours and more, and can terminate in death in the first 2 days), severe (when one or two limbs are crushed for 6-7 hours), moderate (develops without severe postcompressional shock and with moderate impairment of kidney function), and the light form (weakly pronounced disturbances in functions of the kidneys and cardiovascular system).

Victims being examined complain of unlocalized pain in the injured portion of the body, or of its numbing and the impossibility of movements in the joints, weakness, thirst, pain and a heavy feeling in the head, and nausea. The injured portion of the body has abrasions and dents taking the form of ovals and stripes copying the protruding parts of the objects in contact with the body. The skin is pale or moderately cyanotic. Alternating areas of paling, hyperemia, and cyanosis create the impression of marbling. When compression is severe the skin of the limbs is purplish violet. Injured portions of the body are compact and cold to the touch. Small blisters (2-4 mm diameter) filled with serous or bloody fluid appear after a while on the skin in places of intense crushing. Pain sensitivity is absent in the place of compression and distal to it. Presence of these symptoms allows the suspicion that the prolonged crushing syndrome is present, and it permits tentative determination of the severity of injury.

The first portions of urine are dirty-brown in color. Presence of brown urine excludes the light form of illness. Protein, erythrocytes, and columnar cells are detected in urine, even when its color is normal. There is much protein, fresh erythrocytes, hematin crystals, and lumps of myoglobin present in brown urine.

Soon (30-40 minutes after the victim's rescue) the injured limb begins to exhibit noticeable edema, increasing in volume. Areas of edema have a woody consistency, they are sometimes restricted in area (for example in the gluteal regions), and they recall intramuscular hematomas. In distal portions of the limbs the pulse is weak or, more rarely, it disappears due to spasm of arteries and their compression by edemic muscles.

In extremely severe cases the overall condition of victims deteriorates rapidly as edema increases. Sluggishness, inhibition, somnolence, and pallor develop, followed later by cyanosis and jaundice of the skin.

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Arousal, impaired consciousness, delirium, and vomiting are possible. The pupils are severely constricted, and later they may enlarge dramatically; the pulse is rapid and weak. Arterial pressure is low. Heart tones are dull and arrhythmic, and extrasystole is often noted. Abdominal pains, typanites, and signs of irritation of the peritoneum may arise. The tongue is dry, and it is covered with a dark coating. Urine is brown, it has a sharply acidic reaction, its specific weight is high, there is a large volume of sediment, there are numerous fresh erythrocytes, and there is a high concentration of protein (6-12 °/oo) and hyaline and grainy columnar cells. Total anuria often sets in after 200-300 ml of urine are excreted. Blood analysis reveals its thickening coupled with growth in hematocrit, hemoglobin, and the erythrocyte count, neutrophilic leukocytosis (12,000-25,000) with a leftward shift, and eosino- and lymphopenia. If as a result of active antishock and other therapeutic measures these victims do not die in the first 2 days, death often occurs as a consequence of hepatic coma, intestinal gangrene, or sepsis.

In cases of lower severity the disturbances in hemodynamics following rescue from rubble are expressed as a decline in arterial pressure (80-100 mm Hg). The first portions of urine are brown and contain a large volume of sediment. Beginning on the second and third days urine is excreted in small quantities (diuresis 200-400 ml), it acquires a normal color, but it has low specific weight (1.008 and below), and it contains protein, erythrocytes, and columnar cells. If these data are not taken into account and if an analysis is not made of the concentration of urea and nitrogen in blood, which exceeds the normal values and continues to grow, a deceptive impression of a favorable course of illness arises. At the same time an increase occurs in the concentration of potassium and nitrogen (up to 300--600 mg-percent), urea (up to 400-650 mg-percent), creatine, phosphorus, and bilirubin, and the reserve alkalinity and concentration of chlorides, calcium, and sodium decline. As toxemia develops the victim's condition deteriorates; nausea and vomiting arise, and lethal collapse may develop on the 3d-13th days. Hyperkalemia is the immediate cause of death.

Disturbances in the functions of the cardiovascular system, kidneys, and liver are less pronounced among victims with the moderate form. Often immediately after being rescued from rubble they exhibit high arterial pressure (140-150 mm); urine is dark and contains a large volume of sediments. Moderate oliguria is noted later.

Recovery of diuresis in patients may occur gradually or, more rarely, suddenly, with large quantities of urine, salts, potassium, and sodium being eliminated. During this time the distorted impression that the threat to the victim's life had been eliminated may arise. In reality hypokalemia may become the cause of death.

Prompt active therapy extends the toxemic period to the 16th-18th days of illness. This is why general and local complications may set in as early

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as in the toxemic period, to include hypochromic anemia, pneumonia, sepsis, peritonitis, necrosis of skin and muscles, phlegmon, and gangrene of the distal portion of the limb. Traumatic neuritis is noted especially often (M. I. Kuzin, 1959).

Treatment. First medical aid: Subcutaneous injections are made (with syrettes) of 1 ml 1 percent morphine solution (or 1 ml 2 percent pantopon solution or 2 ml 1 percent promedol solution), and 1 ml cordiamine together with 1 ml 10 percent caffeine solution. The casualty drinks 50 gm vodka, a glass of hot tea or coffee, and 4 gm sodium lactate (this can be substituted by the same quantity of sodium hydrocarbonate) to fight acidosis. Vodka is not given to patients in an extremely severe state. After the traumatized limb is freed, a pneumatic splint is applied to it. When it is impossible to apply a splint to the limb, it can be bandaged down tightly. Immobilization of the limb is mandatory even when there is no suspicion of bone fracture. It would be extremely undesirable to use a tourniquet. Application of the latter is indicated after the limb has been intensively crushed for 15 hours and more--that is, in the event of its forthcoming amputation. The tourniquet is applied immediately proximal to the place of injury, without stopping the blood supply to uninjured portions of the limb.

First physician's aid: When examining the victim we must consider the following to be the most informative criteria of his condition in the period of postcompressional shock: General condition, facial color, hemodynamic indices, quantity and appearance of urine, hematocrit, erythrocyte count, and blood plasma bilirubin and potassium. If the patient is unable to urinate, urine should be obtained with a catheter. Patients with the light form of the prolonged compression syndrome are evacuated to a specialized institution of the hospital base, while casualties with the extremely severe form of the syndrome are placed in a hospital for untransportable patients. The remaining victims continue to undergo measures in the antishock ward aimed at controlling shock, hyperkalemia, and acute hepatorenal insufficiency. A (futlyarnyy) and a bilateral paranephric novocaine blockade are performed (entry of novocaine into kidney tissue is dangerous!). When the lower limb is injured 20 ml 0.5 percent novocaine solution is injected into the femoral artery below the groin.

Experimental and clinical data (R. Ya. Gershtenkern, 1964-1969) have demonstrated the high effectiveness of local prolonged moderate cooling of traumatized tissues in the presence of postcompressional shock; in this case the skin temperature must not drop below 16-18°C. Local cooling has a distinct protective action, preventing destruction of some of the injured nerves, muscles, and skin. It should be considered that cooling does not counteract tissue edema already developing, but it can significantly restrict its development when employed early (before development of edema). Signs of successful local cooling include relief of diffuse pain and elimination of a cyanotic or marbled condition of the skin.

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Secondary paling of the skin is the signal for a break in cooling. Cold is applied for 5-7 days. Termination of the growth of edema and warming of tissues in intervals between treatments are indications for termination of local cooling.

It would be suitable to administer antibiotics with a broad spectrum of action to prevent activation of intestinal bacteria and the possibility of infection through injured walls. In addition antibiotics with a broad spectrum of action, especially in the neomycin group (mycerin, colimycin, neomycin), inhibit the action of proteolytic enzymes promoting decomposition of damaged tissues. In the event that peripheral pulse disappears due to high tension of shank and forearm muscles, broad dissection of tissues ("stripe" cuts) and exposure of fascial sheaths, followed by application of sutures onto the skin, is indicated.

Splints, tourniquets, or elastic bandages are removed from damaged limbs not during personal cleansing but rather in the antishock ward, where this is done after preliminary cooling of the limb (for 20-30 minutes) and a (futlyarnyy) novocaine blockade coupled with concurrent intravenous infusion of high molecular weight plasma substitutes.

The victim is allowed to inhale moistened oxygen. The following are infused intravenously: Low molecular weight dextran (for detoxification purposes), 200 ml 20 percent mannitol solution (to reduce reabsorption in the convoluted tubules and to increase plasma osmotic pressure), 250 ml 1-4 percent novocaine solution and 20 percent glucose solution (the latter promotes movement of potassium into the intracellular medium), and 50-100 ml 5 percent gelatin (containing the amino acid glycine) with the goal of providing pain relief and restoring liver function. Spasmolytics are administered concurrently to reduce hypoxia of the kidneys, liver, and intestine: Diaphylline or euphylline (slowly into the vein, 10 ml 2-4 percent solution in a hypertonic glucose solution), heparin intramuscularly (500 units) with the goal of increasing blood anticoagulational activity, and a solution of pipol'fen or dimedrol with the goal of desensitization.

Hydrocortisone (100 mg) and vitamins B_1 (1 ml 0.06 percent solution) and C (1 ml 10 percent sodium ascorbinate solution) should be injected intravenously.

After energetic antishock therapy is provided and hemodynamics are stabilized, patients of this profile would best be evacuated for specialized aid to a traumatological hospital for casualties with limb injuries. Local cooling must be continued as the casualty undergoes transportion to a specialized institution of the out-of-town zone, especially when a tourniquet has been applied; the casualty himself can be kept warm with blankets and heating pads.

The secondary medical worker accompanying such a group of patients must be prepared to resume intravenous infusions of plasma substitutes (in the event arterial pressure drops) and to inject cordiamine and caffeine.

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Specialized aid: Casualties may arrive at the hospital in a state of shock developing as a result of travel. Therefore some of the therapeutic measures indicated above (infusion of dextran, injection of caffeine) must be implemented in the antishock ward of the hospital's receiving department; transfusion of preserved blood may also be necessary. Direct blood transfusion would be even more effective.

In the intermediate period, treatment boils down to adapting general metabolism in damaged tissues to the restricted possibilities of the casualty's body for decontaminating ordinary and pathological metabolites in the liver and to eliminate them and water through the kidneys, to fighting anemia, and to maintaining the body's protective forces.

Computations have shown that the quantity of introduced liquids must exceed diuresis and other losses during the day (fluid eliminated with vomit, wound discharges and the stool) by 500-600 ml.

A carbohydrate-fat diet of sufficient calories (2,000 kcal per day) is prescribed. Milk, vegetables, fruits and fruit juices containing large quantities of potassium are excluded. As a reference point, the weight of patients should decrease by 200-300 gm per day, since synthesis of tissues in severely injured patients lags behind decomposition. Vitamins are injected intravenously or intramuscularly. Use of diuretics is contraindicated, since recovery of diuresis is associated with regeneration of tubular epithelium and opening of the lumen of the tubules coupled with reduction in interstitial edema. When oligoanuria is present hydrogen ions are retained by the body, for which reason sodium lactate must be prescribed (4 gm several times a day) until urine has a weakly alkaline reaction.

Local cooling, which not only reduces metabolism but also decreases burning pains elicited by traumatic neuritis, should be continued.

In the severe form of the illness these measures may turn out to be insufficient; this is why it is important to maintain dynamic observation of the ionic picture, especially of the concentration of potassium and magnesium (7.5 meq is the dangerous limit of blood plasma potassium concentration). Repeated hemodialysis is a reliable method for removing potassium.

Catabolism is decreased by administering anabolic hormones.

Experimental data (R. Ya. Gershtenkern, Ye. M. Kimbarovskaya, Yu. B. Kochetovskiy, A. F. Isakin, 1965-1973) have demonstrated the effectiveness of short sessions of hyperbaric oxygenation (30 minutes at 2-3 atm) in the presence of postcompressional shock and in the toxemic period. Oxygen administered at high pressure eliminates hypoxia in the brain, liver, and other organs and tissues, and it has a positive neurotrophic influence, promoting earlier and fuller regeneration of nervous tissue, prevention of necrosis, and healing of wounds.

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When pronounced disturbances in intestinal functions are accompanied by signs of peritoneal irritation, necrosis in the intestinal mucosa can be suspected. In this case oligemia must be eliminated, and spasmolytics and fibrinolysin must be administered.

Oligoanuria is superceded by a phase of polyuria. If the latter had begun while the patient was in a state of hyperhydration, diuresis must exceed the volume of consumed fluid until edema is eliminated. Hypokalemia is prevented at this time by broadening the diet, permitting fruit juices.

When there are large numbers of casualties requiring aid, the indications for limb amputation must be expanded. If a limb had been subjected to intense compression for more than 15 hours, early amputation is indicated.

During the period of complications the therapeutic measures are aimed at restoring the functions of traumatized limbs and controlling anemia, infectious complications, and local inflammatory-necrotic processes.

Consequences of prolonged tissue compression may include asthenia, worsening of circulation in the traumatized limb, and impairment of sensitivity and movement.

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CHAPTER 4

WOUNDS, INFECTIOUS COMPLICATIONS OF WOUNDS, AND THEIR TREATMENT

General Information on Wounds and the Wound Process

In a modern war, open injuries of varying severity, extent, and location may arise in response to many injurious factors--metallic fragments and bullets, falls, wounding by fragments of glass, rock, and brick, and so on.

We will encounter wounds of soft tissues--skin, subcutaneous fatty tissue, and muscles, compound bone fractures, open joint injuries, wounds of the chest and abdomen, and other severe and extremely severe injuries.

Bleeding, pain, and disturbance of the functions of the damaged portion of the body unavoidably accompany wounds. Presence of wounds always harbors the possibility of infection.

The course of the wound process, development of infectious complications, and the fate of the injured limb and the life of the patient as a whole depend in many ways not only on the location and extent of injury to tissues and infection of the wound by various microorganisms, but also on the depth and nature of injury to soft tissues, bones, joints, and internal organs, and on the initial state of the body. In this connection it is extremely important to clarify the body's reactivity and the severity of injuries, to clarify the clinical pattern, and to forecast the complications.

Fresh limb wounds may be puncture , incised, lacerated, contused, lacerated-contused, crushed, scalp, and gunshot. They can vary in dimensions from point wounds to large wounds occupying one segment of a limb and more. Gunshot wounds can be through and blind.

Wounds are distinguished in shape as perforated, linear, fragmentary, scalloped, polygonal, and complex. Wounds can be longitudinal in relation to the axis of the limb, transverse, oblique, circular, and spiral, with

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and without penetration of the skin and underlying soft tissues. Wounds involving injury of major blood vessels deserve special attention.

The wound classification proposed by S. S. Girgolav still has significance today; according to it, all wounds are divided into two basic groups--those with a large zone of injury and those with a small zone of injury. A large zone of injury to tissues surrounding the wound arises with contused and especially lacerated, crushing, and gunshot wounds caused by bomb and shell fragments.

Crushing wounds offer the greatest difficulties to therapy. As a rule in such cases the skin is highly contaminated, damaged, and separated, and muscles are crushed over significant areas. Microscopic analysis would show that tissues forming the walls of the wound channel and the floor of the wound have undergone degeneration. Edema, swelling, homogenation and fragmentation of collagen fibers, and areas of impaired circulation can be revealed; these are the principal causes of pronounced inflammatory phenomena arising soon after trauma in the skin and especially in subcutaneous fatty tissue, in which foci of extensive inflammatory diffusional infiltration by leukocytes form.

In addition to gross pathological changes in the skin, gross pathology can be noted in muscles. Layers of connective tissue in muscles are edemic and infiltrated by leukocytes with segmented nuclei. Muscle fibers are dystrophically altered, and transverse striations are absent from most fibers. Intercellular spaces contain accumulations of lymphoid cells and individual muscle bundles suffering grossly impaired circulation. Muscle nuclei often do not stain. Muscle fibers vary in thickness, their shape is irregular, staining is nonuniform, and graininess can be seen in some of them--that is, early after trauma muscle tissue exhibits gross degenerative, dystrophic, and inflammatory changes.

Early initial surgical treatment of wounds is especially important in relation to crushing wounds, since inflammation begins to develop in the very first hours following trauma on the background of gross dystrophic changes in the skin and especially in the subcutaneous fatty tissue, and in muscles. Dissection of wounds is not enough in their presence; radical excision of damaged tissues would be desirable.

The severity of trauma is always increased when numerous small, medium-sized, and large vessels are injured.

The clinical pattern and course of gunshot wounds are very variable. The extent of tissue destruction depends on the weight of the missile, and it is proportional to the square of its velocity. When gunshot wounds are present we must consider not only presence of an immediate zone of traumatic necrosis but also a zone of molecular concussion produced by the action of lateral shock. There is no gross destruction in this zone, but the viability of the tissues and their resistance to infection are lower.

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In addition to tissue necrosis and contamination of wounds by pathogenic flora, foreign bodies (bullets, fragments, pieces of clothing) may be a frequent cause of development of severe forms of suppurative and anaerobic infection.

Initial Surgical Treatment of Wounds

Surgery should not be performed in relation to isolated point bullet wounds of soft limb tissues with a small zone of injury, since the probability that wound infection would develop is low.

The main goal of initial surgical treatment is to remove as much dead and dying soft tissues about the wound as possible without detriment to the viability and subsequent functioning of the limb. Thus when injuries are extensive and severe, surgery involves sufficiently extensive dissection of the wound, removal of as much dead substrate as possible, and achievement of free drainage of the wound.

General anesthesia should be provided in the presence of extensive and severe wounds (nitrous oxide, fluorothane, and so on). Local anesthesia is permitted in the presence of small and medium-sized wounds that are not severe, mainly in soft tissues. It would be suitable to add antibiotics to the novocaine solution.

Treatment of the Skin Surrounding the Wound

Prior to treating the skin, the wound is covered over with a multilayered sterile napkin. Chunks of dirt and blood clots are removed from the skin surface with a tampon wetted with benzine; the skin is wiped in the direction from the wound to the periphery. It would be better to clean skin over the perineum, hollow organs, the neck, and the face with 0.5 percent ammonium hydroxide solution or 3-5 percent soap solution. Hair is shaved from about the wound. The skin is once again cleaned with alcohol, wiped dry, and painted twice with 5 percent tincture of iodine (iodonate or (rokal)), after which it is covered with sterile cloth.

Initial Surgical Treatment Techniques

Surgical treatment involves dissection and excision of injured tissues, drainage of the wound, and subsequent immobilization of the damaged limb. Treatment begins with dissection and excision of the dermal margins of the wound. Blood clots, foreign particles, loose tissue fragments, and bone fragments are removed deep down into the wound. Then the wound is meticulously inspected to reveal its real dimensions and the severity of injury. If inspection of the walls and floor of the wound is difficult, a dermal wound could be enlarged while an aponeurosis can be additionally dissected.

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Excision of portions of muscle that are unviable and fated to necrosis over a maximum possible area is the most difficult and serious stage of initial surgical treatment of wounds. Unviable muscles are dull in appearance, they do not bleed, and they do not contract when stimulated by tweezers or some other instrument. When processing muscles it would be suitable to use compresses soaked in hot physiological solution, which makes it possible to reveal the viability of muscles better.

The wounded area of an aponeurosis is excised and the aponeurosis is dissected over a greater or lesser area depending on the extent of damage to it and underlying muscles. Injured small vessels are ligated, and injured major vessels are also ligated or their conduction is restored by means of a vascular suture.

When nerve damage is discovered the crushed ends of the nerves are excised, after which a primary epineural suture can be applied. It is especially important to see that the end of the nerve is not sutured to the end of a tendon in the wound.

During the operation it would be desirable to rinse the wound with a stream of antiseptic solution (rivanol, nitrofurazone, hydrogen peroxide) from a rubber bulb or syringe with the goal of flushing small fragments of necrotic tissues or foreign particles from the wound.

When capillary hemorrhaging from muscles is significant the area of bleeding should be pressed down with a wad or napkin moistened with hot physiological solution. When bleeding occurs from parenchymatous organs the area of bleeding can be packed with a stick-mounted seal or a chunk of muscle tissue. Meticulous hemostasis is one of the prerequisites for uneventful healing of the wound (without complications).

When a compound fracture is present, in addition to treating the soft tissue wound the damaged bone must undergo processing. The forceps or a chisel is used to remove highly contaminated fragments of damaged bone and small contaminated bone scraps. All medium-sized and large bone fragments, even loose ones, must be preserved. They are processed by submerging them in an antiseptic or antibiotic solution. After the soft tissue wound is processed they should be returned to their places. Removal of large fragments and especially resection of fragments can be the cause of bone defects. Extensive bone dissection cannot prevent a complicated course of wounds, but as a rule they are the cause of a failure of fracture mending.

Tendons must be restored to the extent possible. Sutures are not applied to aponeuroses and fasciae, since this can lead to arisal of the hypertensive ischemic syndrome in the postoperative period in connection with possible edema of muscles.

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When gunshot wounds are present surgical treatment begins with dissection of the entrance and exit holes of the wound, after which the wound channel is examined to the extent possible and injured tissue is removed.

A primary blind suture is permissible only in rare cases following radical excision of the margins and face of the wound, when no contaminated and unviable tissues or foreign particles remain, when there is no damage to major blood vessels, and when the victim can be kept under observation at the given stage for not less than 7-8 days. The wound should be closed beginning with its deeper layers, applying convergent sutures on muscles, which will make it possible to avoid pockets and cavities, but the number of sutures must not be excessive. Wherever the skin is stretched, only rare convergent sutures are permissible. When skin defects are present, after unviable tissues are excised primary dermotoplasty using a complete free or bridge-type sliding panniculus would be indicated.

When extensive contused and crushing wounds are present, wounds are not sutured shut after primary surgical treatment; instead, in the best case occasional convergent sutures are applied and a drainage tube is inserted into the corner of the wound. The wound can be drained with the assistance of strips of thin rubber or thin silicone tubes with openings at their ends. Active drainage produces a better impact.

The wound must be left open if initial surgical treatment was not sufficiently radical.

A primary-postponed suture is applied 5-6 days after initial surgical treatment, while there are still no signs of granulation in the wound and there are no signs of infectious complications.

An early secondary suture can be applied in the first 7-14 days after wounding, if the casualty's overall condition is satisfactory and a granulating wound with movable edges is present. Sutures consisting of special plates or buttons which make it possible to bring the margins of the wound close together and hold the sutures together without cutting through the skin margins until the wound is completely healed have advantages.

A late secondary suture produces poorer results because the margins and floor of the wound will have undergone scarring by this time. The wound margins must be excised, mobility of the margins must be recovered, and only after this can the sutures be applied.

Secondary dermatoplasty: When wounds are extensive, and bright red, fine granulations are present, despite profuse suppurative discharge secondary dermatoplasty is indicated, employing the Yanovich-Chaynskiy, Tirshch method with small dermal panniculi and, more rarely, using postage stamp complete or split dermal panniculi that do not completely cover the wound surface.

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Small dermal panniculi do not hinder drainage of suppurative discharge from deep within the wound, they take well, and they provide a possibility for covering over extensive dermal defects. Autodermal transplants have bacteriostatic and bacteriocidal properties, and they are highly resistant to microbes present in the wound (P. A. Pervushkina, 1955; O. N. Markova, 1959, 1968). The surgical technique is simple, and it produces good results soon after trauma.

Secondary wound treatment: Sooner or later after receiving their wounds, some patients will require secondary treatment. Such wounds must not be closed with sutures.

Indications for primary osteosynthesis and its methods: At the time of initial surgical treatment of compound fractures, the question as to the permissibility and suitability of osteosynthesis using metallic structures must be resolved. Primary osteosynthesis with embedded metallic structures is indicated only following radical initial surgical treatment and when the zone of injury is small (an exception can be made only with fractures of the femur).

When femoral fractures are transverse-oblique, fragments can be secured firmly with implanted intraosteal thick metallic pins; in the presence of oblique fractures the indications are greater for osteosynthesis with detorsional-compressional plates, with the screws attached crosswise.

Osteosynthesis employing embedded metallic structures is not indicated when splintered fractures of the femur occur. Skeletal traction produces good results when the conditions are right. If the patients are to be evacuated, a high hip cast should be applied.

A metallic pin can be used for osteosynthesis of the ulna, and a detorsional-compressional plate can be used with the radius.

When compound fractures of the shoulder and shank are present, specialized aid can consist of compressional osteosynthesis using modern distractional-compressional apparatus.

Combined osteosynthetic methods in which extrafocal perosteal fixation is combined with embedded metallic structures that do not worsen the hemodynamics of the injured limb (screws, bolts with lock nuts, pins with thrust pads) are of interest.

Massive embedded metallic structures are not indicated in the presence of shank fractures coupled with extensive bruising and crushing of muscles, since their use would worsen circulation in the fracture area due to extensive sloughing of the periosteum or destruction of bone marrow, which increases the frequency of complications accompanying fractures and leads to retarded consolidation of fractures and failure of their knitting.

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When stable fractures and fractures not involving displacement of bone fragments occur in all locations, high slit circumferential casts with "windows" in the vicinity of wounds or without them are indicated.

After initial surgical treatment of soft tissue wounds, application of plaster splints or semisoft (plastic) molded splints which immobilize areas of limb injury is quite sufficient.

Thus initial surgical treatment and subsequent treatment include the methods of restorative surgery permitting restoration of the anatomy and function of damaged organs in the shortest time.

Postoperative patient care: In the first days after wounding and initial surgical treatment, damaged limbs must be elevated. Local tissue hypothermy produces good results. The condition of the victim and his wound must be monitored in the postoperative period, especially if closed sutures are applied at the time of initial surgical treatment.

Wound Infection Agents

It is commonly known that irrespective of the nature of trauma, fresh wounds are seeded by representatives of normal microflora. In addition to anaerobic *Clostridium*, aerobic soil microorganisms, *Staphylococcus*, and intestinal micororganisms can be cultured from fresh wounds. Microbial contamination of wounds is not yet an infectious complication, and even when microbial contamination is considerable this complication may not even develop. The condition of tissues upon which microbes settle is important. All microorganisms are dangerous in the presence of crushing and gunshot wounds.

It is commonly recognized today that the overall condition of the patient's body at the time of an agent's introduction (the state of his immunobiological processes) has important significance to development of wound infection. The condition of tissues in the injured area is no less important. The more circulation is disturbed in the wound area and the more crushed tissues there are, the more probable is development of infectious complications.

The wound process involves constant interaction between microorganisms and the macroorganism.. Important to development of wound infection are the number of wound infection agents introduced into the wound, the features of the agent itself, and its pathogenicity (virulence).

Pathogenic microorganisms have tox : and destructive action upon tissues of the macroorganism during the time of development of the infectious process. Bacterial toxins are the principal pathogenic factor of bacteria. Most of them are proteinaceous substances having biological activity exceeding the action of the strongest chemical poisons by hundreds and thousands of times (Ye. M. Gubarev, 1952; Yu. V. Galayev, 1969).

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True agents of wound infection (anaerobic microorganisms, *Streptococci*, *Staphylococci*) elicit specific immunological reactions in the patient's body serving as indications of the body's activity: The more active the immunity indices are, the faster recovery processes proceed (I. V. Davydovskiy, 1946; L. S. Kryshtal'skaya, 1965).

Therapeutic measures can cause changes in the microflora: Prompt and proper surgical treatment of wounds, dermatoplasty, immobilization of limbs, and use of antibiotics and other chemical preparations.

The body's resistance to infection may be local, regional, or general. Local immunity depends in part on the type of tissue and the features of its blood supply. The protective action of regional lymphatic nodes, phagocytosis, intracellular digestion, and death of microbes are important factors in the immune process.

The intensity of local inflammation provides an indication of the strength with which the body is capable of reacting to an invading agent, but it is not always parallel to its virulence. It is precisely in the case of virulent microbes that the bacterial attack can proceed unexpectedly and intensively, such that the local defensive reaction barely manifests itself or is entirely absent, while the signs of general infection reveal themselves quickly and are sometimes clearly pronounced. Consequently if the body's defenses cannot oppose infection, intensive, sometimes unlimited tissue decomposition and penetration of bacteria into lymphatic and blood vessels followed by general infection occur. Bacteria circulating in the bloodstream may cause bacteremia to persist for a long period of time, and they penetrate more frequently into those places where the capillary network is the most developed, creating secondary foci of infection there. Thus suppurative foci arise far away from the wound area. The severity of illness depends on accompanying toxemia. Bacteremia does not occur without toxemia. In some cases the pattern of general infection arises following lengthy local wound infection. Bacterial invasion elicits classical cellular and humoral defensive reactions in the body. In normal conditions some agents are destroyed by phagocytes within the cells a short time after phagocytosis. Virulent bacteria are not destroyed by phagocytes; they may destroy leukocytes by their toxins, or they may reproduce within the cell following phagocytosis. A certain time after phagocytosis of such bacteria, the cells disintegrate, and the microbes enter the bloodstream. Bacteria within cells are not subjected to the action of most antibiotics, and thus the infection persists for a long time in the body.

Microflora found in wounds during the postoperative period include flora not removed at the time of initial surgical treatment and microbes entering the wound secondarily from the air, clothing, hospital linens, and so on.

When soft tissue wound suppuration is intense, and in the presence of phlegmons and osteomyelitis, 80 percent of the cultures reveal microbial associations consisting of two to six components, containing representatives

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of both purulent and putrefactive microflora (*Staphylococcus*, *Proteus*, *Bacillus pyocyaneus*, and so on).

Sensitivity of the Agents of Wound Infection to Antibiotics and Other Chemotherapeutic Preparations

Information on the spectrum of action of antibiotics is not enough for successful treatment of patients. We must know the sensitivity of the agent of wound infection to the chemotherapeutic preparation in each case.

In order to correctly evaluate the agent's sensitivity to the antibiotic we must determine the minimal inhibiting concentration (MIC), which is defined as the lowest concentration of antibiotic capable of suppressing development of the microbe.

All microbes are subdivided on the basis of the MIC into sensitive, moderately sensitive, and resistant. (Kirby, 1957).

Strains of microorganisms which cease to grow at antibiotic concentrations determined in the blood of a patient who had used the antibiotics in their usual therapeutic doses are called sensitive.

Strains requiring a concentration of antibiotics created in the blood following administration of the maximum dose of the preparation to suppress vital activities are called moderately sensitive.

Strains that stop growing only after very high concentrations of antibiotics, which cannot be created in the living body, are called resistant.

For therapeutic purposes it would be important to consider the concentration of the antibiotic in the zone of infection, where it must be higher than in blood, and this concentration must be maintained for a sufficiently long time, enough to fully affect the agent (A. M. Marshak, 1964).

Kirby's scheme is tentative because the criteria of sensitivity may often depend on many factors--the species of the agent, the location of the infection process, the means by which the preparation is administered, and its possible concentration in the zone of infection.

There are different methods for determining sensitivity of microbes to antibiotics; these methods have not been standardized yet.

Sensitivity is usually determined with paper indicator disks or serial dilutions of antibiotics in liquid or solid nutrient media. Various quick methods can be employed.

The method of indicator paper disks is a commonly accepted one for determining sensitivity for practical purposes, but it provides only orientational (qualitative) data.

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The serial dilution method is the most precise, but it is cumbersome and is rarely employed for practical purposes.

Microorganisms isolated from wounds exhibiting various suppurative processes ("hospital" strains) differ significantly in sensitivity to antibiotics from those isolated from wounds during initial surgical treatment ("street" strains). There are much fewer strains among the latter that are resistant to the most widespread antibiotics.

In the first years that penicillin was used, "street" *Staphylococcus* strains occurring in the presence of acute trauma were sensitive to this drug in 88-90 percent of the cases; their sensitivity to penicillin has decreased in recent years. Growth in their resistance can be explained by spreading of the hospital infection among the public, as a result of which resistant "hospital" strains are replacing the "street" strains.

According to 1975 data of the Central Scientific Research Institute of Traumatology and Orthopedics the resistance of *Staphylococcus* "street" strains is 20 percent on the average in relation to penicillin, streptomycin, and tetracycline.

The resistance of *E. coli* cultures ("street" strains) to these antibiotics is also low, which provides the grounds for using them during initial surgical treatment of wounds.

The percentage of stable *Staphylococcus* strains isolated from suppurative wounds is significantly higher than that of strains isolated during initial surgical treatment, today's percentages being 60 for penicillin, 34.2 for streptomycin, 33.4 for tetracycline, 41.7 for erythromycin, 10.4 for monomycin, 33.9 percent for metitsillin, and 17.5 for lincomycin.

The greatest percentage of resistant *Staphylococcus* is observed with chronic suppurative processes (chronic osteomyelitis, burns). This is associated with the fact that adaptation to antibiotics by sensitive *Staphylococcus* strains occurs with prolonged antibiotic therapy. Multiple and cross resistance as well as the state of the body's defenses, which are often suppressed in such patients, have significance.

In recent years the resistance of *Bacillus pyocyaneus* has been 88 percent for streptomycin, 72 percent for tetracycline, 58 percent for monomycin, and 12.5 percent for garamycin. *Proteus*, *Klebsiella*, and *E. coli* are somewhat more sensitive to the same antibiotics, but their resistance to the most widespread preparations (streptomycin, tetracycline, monomycin) is also high, being 52-65 percent on the average. Most strains are sensitive to ampicillin, ceporin, neomycin, and garamycin.

Investigation of the sensitivity of cultures, isolated in the presence of suppurative wound infection, to nitrofuran preparations, particularly the new soluble preparation furagin K (solafur) revealed that 70.8 percent of

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Staphylococcus strains were sensitive to solafur; strains sensitive to solafur also dominate among *Proteus* and *E. coli* strains, while *Bacillus pyocyaneus* strains are resistant to it.

Most microbial associations isolated from suppurative wounds are sensitive to the combination of solafur with antibiotics--tetracycline, monomycin, ampicillin, neomycin.

Sensitivity of wound microflora to sulfanilamide preparations is determined in liquid synthetic medium. *Staphylococcus* and *E. coli* strains sensitive to sulfanilamides dominate today.

When microbial associations exhibit stable resistance to certain antibiotics, reliance must be placed on combined treatment using several synergistically acting antibiotics. The choice of the combination of antibiotics must be based on their mechanism of action, and only those antibiotics whose action is intensified by the others, creating a synergistic effect, should be combined.

Almost all antibiotics combine well with sulfanilamide and nitrofuran preparations.

In no case should aminoglycoside antibiotics be combined (streptomycin, gentamicin, kanamycin, monomycin). Combining penicillin, which acts on multiplying forms of microbes, with tetracycline, which halts multiplication of microorganisms and thus cancels out the batericidal effect of penicillin, is not recommended.

Prevention of Wound Infection

Preventive Use of Antibiotics

Extensive and deep wounds of soft tissues coupled with contusion and crushing of subcutaneous fatty tissue and muscles, compound fractures involving significant circulatory impairment in the injured portion of the limb, and gunshot wounds are characterized by the largest number of serious suppurative complications.

All casualties with extensive wounds exhibit direct indications for prescription of antibiotics following wounding, during initial surgical treatment, and in the postoperative period.

Antibiotics in the tetracycline group having a broad spectrum of action may enjoy the most widespread use in the presence of severe traumas (tetracycline hydrochloride for intramuscular injection, morphocycline for intravenous or intraosteal injection). Tetracycline exhibits a tropism for bone tissue, and it persists within it at high concentrations for a long time. The combination of penicillin and streptomycin may still enjoy use for preventive purposes in the presence of acute trauma. Use of

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antibiotics having a broad spectrum of action (monomycin, ceporin, ampicillin together with oxacillin, and so on) for preventive purposes is also highly effective. But it would be better to hold them in reserve for patients with infectious complications of the wound process. Moderate and massive doses of antibiotics should be used for preventive purposes.

To intensify the bacteriostatic and bactericidal action of antibiotics, they should be combined with peroral use of long-acting sulfanilamides (sulfapyridazine, sulfadimethoxine, sulfamonomethatoxine).

It is extremely important that the antibiotic reaches the infection zone in therapeutic concentrations. High therapeutic concentrations in the infection zone could be achieved with local, (intravenous, intraosteal), and intraarterial injection. Local antibiotic injection is the simplest and most effective method. For this purpose the antibiotics are diluted as a rule in 5-10 ml 0.5 percent or 0.25 percent novocaine solution and given as one, two, or three injections near the wound. When penicillin and streptomycin are used for preventive purposes, a dose of 500,000 AU [active units] penicillin, 250 mg streptomycin, and 100-200 mg tetracycline should be entirely sufficient.

After the antibiotics are injected, they persist at a high concentration in the wound for 24 hours and more. This can be explained by the fact that patients with contused and crushed wounds have extensive areas of hemorrhaging in soft tissues, followed by protein breakdown. Antibiotics diffuse slowly into blood from such wounds.

Introduction of antibiotics deep into a wound through drain tubes (rubber, silicone, and so on) would be useful if a closed-loop system precluding contamination of the wound by environmental air could be created.

For 5-6 days in the postoperative period it would be suitable to employ the same antibiotics that had been administered during initial surgical treatment.

Considering the greater resistance of microorganisms to penicillin, its one-time intramuscular dose must be not less than 1 million AU. Because penicillin is eliminated from the body quickly, it must be injected intramuscularly 4 times a day. The one-time dose of streptomycin is 250-500 mg twice during the day. Tetracycline must be injected intramuscularly at a dose of 200 mg 2 to 3 times a day, and morphocycline must be administered intravenously at a dose of 150 mg, diluting it in 225 ml 5 percent glucose solution.

Despite preventive use of antibiotics the surgeon must always remember that observance of the strictest aseptic conditions is a mandatory prerequisite in the care of postoperative patients.

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Immunization of Patients With *Staphylococcus* Anatoxin

Immunization of patients with *Staphylococcus* anatoxin immediately after trauma is an extremely effective way to prevent *Staphylococcus* infection. Authors who have made extensive use of anatoxin for preventive purposes (Ye. Ye. Tsipenyuk, 1963; K. P. Voronov, 1967; V. A. Proskurov, 1969; I. A. Movshovich et al., 1969, etc.) observed a high titer of *Staphylococcus* anatoxin in the blood of patients, this corresponding with the good results achieved.

Treatment of Suppurative Wound Infection

When signs of wound infection appear (worsening of general condition, hyperemia of the skin, pain in the wound, and so on) conditions permitting free drainage of the wound must be provided: Sutures must be removed if the wound had been sutured, and a drain tube and tampons should be introduced. If drainage is inhibited, it would be suitable to subject the wound to secondary surgical treatment and apply (kontrapertury).

A. V. Vishnevskiy's Method

When the danger of arisal or development of wound infection exists, A. V. Vishnevskiy recommended using a novocaine blockade employing weak solutions (0.25 or 0.5 percent) of novocaine away from the wound, in combination with application of an oil-balsam dressing.

Vacuum Method

When deep wounds are complicated by a suppurative infection, the vacuum method is extremely useful, permitting removal of loose necrotic tissue fragments and pathological granulations from the walls and floor of the wound, and reduction of the wound's contamination by microbes. Vacuuming also softens scar tissue and improves blood supply to the tissues. The method should be used in integration with surgical treatment and antibiotic therapy.

Sufficiently powerful vacuum pumps must be used with this method.

Use of Proteolytic Enzymes

Proteolytic enzymes (trypsin, chymotrypsin, chymopsin, hygrolytin, and others) are enjoying increasingly greater use in the treatment of complicated soft tissue wounds and compound fractures. These preparations subdue suppurative complications more effectively and in a shorter period of time.

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V. I. Struchkov, A. V. Grigoryan, V. K. Gostishchev, S. V. Lokhvitskiy, and L. S. Tapinskiy (1970) developed the basic methods of proteolytic enzyme therapy. One of them involves the following: The suppurative wound is rinsed with hydrogen peroxide solution, it is dried to the extent possible, and then it is loosely filled with tampons moistened with 1 percent or 2.5 percent solution of enzymes dissolved in 10 percent table salt solution or 25 percent magnesium sulfate solution. It would be best to change the dressings daily.

Use of trypsin, chymotrypsin, chymopsin, and other proteolytic enzymes makes it possible to achieve rejection of necrotic tissues early, and it promotes abatement of inflammatory phenomena; healthy granulations appear in wounds, and epithelialization begins. Proteolytic enzymes may be combined with antibiotics. Irrigation of wounds with proteolytic enzymes may be the final stage of vacuuming.

In addition to local use on wounds, trypsin and chymotrypsin can be injected intramuscularly in 5 mg doses dissolved in 1-2 ml 0.5 percent novocaine solution two times a day.

Use of proteolytic enzymes shortens the exudative phase of inflammation, destroys bacterial toxins, reduces the resistance of suppurative flora to antibiotics, increases the blood antibiotic concentration, and improves capillary circulation, which is extremely useful in the presence of suppurative-inflammatory and necrotic processes.

Use of Bacteriophages

Analogous phages are used in the treatment of suppurative wounds exhibiting *Staphylococcus*, *Bacillus pyocyaneus*, *E. coli*, and *Proteus* infection. The indication for such treatment is presence of extensive granulating wounds with profuse purulent discharge and having an unpleasant odor. The procedure for using bacteriophage is as follows: During the time that dressings are changed the wounds are irrigated with hydrogen peroxide solution, dried with sterile tampons, and then covered with gauze napkins amply wetted with bacteriophage. Dressings are changed daily. On the average the one-time dose is 10-20 ml.

After bacteriophage therapy the unpleasant odor disappears, the quantity of purulent discharge decreases, and healing proceeds more actively.

Use of Antibiotics

When prescribing antibiotics for therapeutic purposes we must determine the sensitivity of microbes to them, since only in this case would their use be purposeful. The possible concentration of antibiotics in the infection zone should be considered when choosing the dose and means of administration of antibiotics (Table 3).

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Table 3. Antibacterial Chemotherapeutic Preparations Used for Prevention and Treatment of Wounds and Wound Infection

	Preparation	Administration	Dose		Spectrum of Action
			One-Time	Daily	
Penicillins	Benzylpenicillin	Intramuscular	200,000-1,000,000 AU	800,000-4,000,000 AU and more	Gram-positive bacteria
		Intravenous	200,000-1,000,000 AU	800,000-4,000,000 AU and more	" "
		Intraarterial	200,000-1,000,000 AU	800,000-4,000,000 AU and more	" "
	Phenoxymethyl-penicillin	Peroral	200,000-400,000 AU	800,000-1,600,000 AU	" "
	Ekmonovocillin	Intramuscular	300,000-600,000 AU (once during the day)		" "
	Bicillins:				
	1	Intramuscular	300,000-600,000 AU (once during the week)	1,200,000 AU (twice during the month)	" "
	2	Intramuscular	400,000-800,000 AU (once during the week)	1,600,00 AU (twice during the month)	" "
	3	Intramuscular	300,000-600,000 AU (once during the week)		" "
	5	Intramuscular	600,000-1,200,000 AU (once during the week)		" "

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Penicillins				
Semisynthetic Penicillins				
Methycillin	Intramuscular	1-2 gm	4-12 gm	Gram-positive bacteria
Oxacillin	Intramuscular	1-2 gm	6-9 gm	"
	Intravenous	1-2 gm	6-8 gm	"
	Peroral	500 mg	4-8 gm	"
Cloxacillin	Intramuscular	1 gm	4-6 gm	"
	Peroral	500 mg	4 gm	"
Dicloxacillin	Intramuscular	0.5 gm	2-6 gm	"
	Peroral	250-500 mg	4 gm	"
Ampicillin	Intramuscular	250-500 mg	1-5 gm	Broad spectrum of action
	Intravenous	500 mg	1-5 gm	"
	Peroral	500 mg	1-5 gm	"
Carbenicillin	Intramuscular	1 gm	4-30 gm	"
	Intravenous	1 gm	4-30 gm	"
Cephalosporins				
Ceporin (Cephaloridine)	Intramuscular	500 mg-1 gm	2-6 gm	Gram-positive bacteria
Cephalexin	Intravenous	500 mg	2-6 gm	"
	Peroral	500 mg	2 gm	"
Macrolides				
Erythromycin (base)	Peroral	250-500 mg	800 mg-2 gm	Gram-positive bacteria
Phosphate and Ascorbinate	Intravenous	200 mg	600 mg-1 gm	"
Oleandomycin (Phosphate)	Peroral	250 mg	2 gm	"
Triacetyl-oleandomycin	Intramuscular	500 mg	1-2 gm	"
	Intravenous	500 mg	1-2 gm	"
	Peroral (as a suspension)	250-500 mg	1-2 gm	"
Novobiocin	Peroral	250-500 mg	1-2 gm	"
Ristocetin (Ristomycin)	Intravenous	300 mg	1-1.5 gm	"
Vancomycin	Intravenous	500 mg	1.2-4 gm	"
Lincomycin (Lincocin)	Intramuscular	500-600 mg	1.2-4 gm	"

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Macrolides	Clindamycin (7-Chlorlincomycin; dalacin)	Peroral	500-600 mg	2-4 gm	Gram-positive bacteria
		Peroral	500 mg		
		Peroral	150-300 mg	600 mg to 1-2 gm	" "
	Fusidic Acid (Fusidin)	Peroral	250-1,000 mg	2-3 gm	" "
Tetracyclines	Tetracycline (Hydrochloride)	Peroral	250 mg	2 gm	Broad spectrum of action
		Intramuscular	100 mg	2 gm	" "
	Morphocycline	Intravenous	200-400 mg	800 mg	" "
	Oxyglucocycline	Intravenous	250 ml	1-2 gm	" "
		Intramuscular	100-200 mg	300-500 mg	" "
	Chlortetracycline (sodium salt)	Peroral	100-200 mg	600 mg	" "
		Intravenous	100 mg	300 mg	" "
Combined Preparations with Tetracycline	Oletetrin	Peroral	250-500 mg	2 gm	" "
		Intravenous		1 gm	" "
	Oleomorphocycline	Intravenous	200 mg	600 mg	" "
	Sigmamycin	Intramuscular	100 mg	200-300 mg	" "
		Intravenous	250 mg	500 mg	" "
	Tetraolean	Intramuscular	100 mg	200-300 mg	" "
		Intravenous	250 mg	500 mg	" "
	Chloramphenicol (Levomycetin)	Peroral	500 mg-1 gm	2-3 gm	" "
	Levomycetin Sodium Succinate	Intramuscular	0.501.5 gm	2-5 gm	" "
		Intravenous	0.5-1.5 gm	2-6 gm	" "
Aminoglycosides	Streptomycin (Sulfate and Dihydrostreptomycin Sulfate)	Intramuscular	500 mg-1 gm	2 gm	" "
	Neomycin	Local			" "
	Kanamycin	Intramuscular	500 mg	2 gm	" "
		Intravenous	500 mg	2 gm	" "

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Polymyxins	Gentamicin (Garamycin)	Intramuscular	40-80 mg	120-240 mg	Broad spectrum of action
	Monomycin	Intramuscular	250 mg	750 mg-1.5 gm	" "
	Polymyxin B	Peroral	500 mg	1-2 gm	" "
		Intramuscular			
	Polymyxin M	Local	500 mg	2-3 gm	" "
Sulfanilamides	Sulfapyridazine	Peroral		Day 1--1-3 gm, subsequent days--500 mg-2gm	" "
	Sulfadimethoxine (Madribon)	Peroral	500 mg		" "
	Sulfamono-methoxine	Peroral			
	Trimethoprim + Sulfamethoxazole (Bactrim, Biseptol)	Peroral	160+800 mg	320+1,600 mg	" "
Nitrofurans	Furacillin	Local			" "
	Furagin (Furazidin)	Peroral	100 mg	0.8-1 gm	" "
	Furadonin	Peroral	100 mg	0.8-1 gm	" "
	Furazolin	Peroral	100 mg	0.8-1 gm	" "
	Furazolidone	Peroral	100 mg	0.8-1 gm	" "
	Furacrylin	Peroral	100 mg	0.8-1 gm	" "
	Furazonal	Peroral	100 mg	0.8-1 gm	" "
	Furagin K (Solafur)	Intravenous	300 mg	1.0 gm	" "
		Local	500 mg	0.1 % solution	" "
	Nalidixic Acid (NegGram)	Peroral	250-500 mg	2-4 gm	" "

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Special attention should be turned to treating patients with *Staphylococcus* infection, which has become widespread in recent years. The parenteral means of administration is used more often so that a therapeutic concentration of antibiotics could be achieved in blood and in the zone of infection, and only a few antibiotics are prescribed perorally. In the event the agent is sensitive, treatment of *Staphylococcus* infection can begin with the most widespread antibiotics (benzylpenicillin, erythromycin, oleandomycin, ristomycin), keeping the newer, penicillinase-resistant antibiotics (methycillin, dicloxacillin, oxacillin) in reserve.

Lincomycin and fusidin, which have a certain tropism for *Staphylococcus* infection, have recommended themselves well in the treatment of bone tissue infection. Lincomycin is prescribed at a dosage of 500-600 mg two times a day intramuscularly for 2-4 days, and then perorally 500 mg four times a day, for up to 10-12 days when infection is acute. For a chronic infection the course of treatment is not less than 30 days.

When mixed infections are present it is difficult to select an effective antibiotic due to the high resistance of microbial associations and their Gram-negative components to many of them. In such cases antibiotics with a broad spectrum of action are effective--monomycin, kanamycin, ampicillin, carbenicillin (pionene), cephalosporin, gentamicin (garamycin). Tetracycline is not very effective against suppurative infection due to high resistance of microflora to it, but complex preparations in which it is included (tetraolean, oletetrin, olemorphocycline, sigmamycin) are excellent.

When microbial associations are stably resistant to certain antibiotics reliance should be placed on combined treatment using several synergistically acting preparations. The choice of antibiotic combination must be based on the mechanism of action of the antibiotics, and only those whose action is intensified by others with combined use (synergistic effect) should be combined.

Table 4 shows combinations of antibiotics used most often to treat wound infection.

Aminoglycoside antibiotics must not be combined with each other (streptomycin, neomycin, gentamicin, kanamycin, monomycin). Combination of penicillin, which acts upon multiplying forms of microbes, with tetracycline, which halts multiplication of microorganisms and thus precludes the bactericidal effect of penicillin, is not recommended.

When complex infections are present in limb wounds coupled with impaired circulation, the antibiotics would best be delivered to the zone of infection by making several injections around the wound or administering the antibiotic intraosteally. The antibiotic course of treatment is not less than 7-10 days.

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Table 4. Suitable Combinations of Antibiotics Used Most Often to Treat Wound Infection

Penicillin G and aminoglycosides (streptomycin, monomycin, kanamycin, garamycin-gentamicin)	Tetracyclines (oxytetracycline, morphocycline) and macrolides (erythromycin, oleandomycin)	Aminoglycosides and macrolides (erythromycin, oleandomycin)
Penicillin G and semisynthetic penicillinase-resistant penicillins (methycillin, oxacillin, cloxacillin)	Tetracyclines (all) and lincomycin (lincocin, clindamycin-dalanin)	Aminoglycosides and lincomycin (lincocin, clindamycin-dalacin)
Semisynthetic penicillins and aminoglycosides	Tetracyclines (all) and novobiocin	Aminoglycosides and ceporin (ceporin, cephaloridine)
Semisynthetic penicillinase-resistant penicillins and semisynthetic penicillinase-sensitive penicillins (ampicillin)	Antibiotics combining well with sulfanilamides and nitrofuran preparations	Levomycetin (levomycetin succinate-chloride) and macrolides

Administering antibiotics to patients exhibiting heightened sensitivity to them is categorically prohibited; instead, antibacterial therapy is based on sulfanilamide and nitrofuran preparations. In exceptional cases antihistamine preparations (dimedrol, suprastin, pipol'fen, and others) should be prescribed together with antibiotics.

When weakened severe casualties require long antibiotic treatment, antifungal preparations should be used for preventive purposes (nystatin, levorin, and so on).

In cases where antibiotics are used for therapeutic purposes, an especially great deal of attention should be turned to enhancing the protective mechanisms of the patient's body. This is why resources stimulating nonspecific

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immunological reactions must always be prescribed in combination with antibiotics, to include blood and plasma transfusion and administration of gamma-globulin, bacterial polysaccharides (prodigiozan, lysozyme), pyrimidine bases, as well as vitamins, vaccines, and serums.

Use of Nitrofurans

Nitrofuran derivatives retard growth of microorganisms resistant to sulfanilamides and antibiotics, and therefore they are especially indicated for the treatment of long-persisting wounds. Furacillin (1:5,000 aqueous solution) applied as a moist dressing on a wound has an effect on Gram-negative and Gram-positive flora. Furazolidone, furadonin, furacrylin, furagin, and others are prescribed perorally. They can be used in combination with antibiotics. In the presence of severe bacterial infections the soluble nitrofuran preparation Furagin K or solafur is used with positive results, both applied locally to the wound and intravenously.

Use of Sulfanilamides

Combined use of antibiotics and long-acting sulfanilamides (sulfadimethoxine, sulfamonomethoxine, and others) is especially effective. These preparations are distinguished by the fact that they are readily assimilated when taken perorally, they achieve high concentrations in the blood, and they are retained for a long time by the body. This affords a possibility for prescribing them less frequently and in relatively small doses--1 gm two times during the first day, and then the dose is decreased beginning with the second day to 1 gm once a day. The average duration of the course is 5-6 days.

Use of *Staphylococcus* Anatoxin

Staphylococcus anatoxin is an inherent part of modern integrated therapy of suppurative complications.

Long treatment course using native *Staphylococcus* anatoxin: Injections are made at 2-3 day intervals; the dosage is increased gradually (0.1, 0.2, 0.3, 0.4, 0.6, 0.8, 1, 2 gm). When the indications are present, the same pattern of injections is repeated 2-3 weeks later. Prescribing copious drinking of alkaline beverages to patients is recommended after this treatment course ends.

Short treatment course using adsorbed anatoxin: Injections are given at 10-15 day intervals at doses of 0.5, 1, and 2 gm. When the short course is employed, the effect sets in 2-3 weeks after the beginning of treatment, and it expresses itself as a cessation or decrease of purulent discharge, normalization of blood (SR*, leukocytosis), and a decrease in temperature.

*According to the international system of units, SR is erythrocyte sedimentation rate.

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Treatment of Sepsis

When development or arisal of sepsis is threatened, the source of sepsis must be established and steps must be taken to eliminate it as quickly as possible. Intravenous injections should be given of bactericidally acting antibiotics in maximum therapeutic doses, and when possible the patient should be subjected to passive immunization, taking the form of infusion of hyperimmune plasma. *Staphylococcus* sepsis is fought with anti-*Staphylococcus* hyperimmune plasma or *Staphylococcus* gamma-globulin.

Protein, water, and electrolyte metabolism must be regulated, the activity of the heart, liver, and kidneys must be monitored, and the body should be saturated with vitamins.

Physical Methods of Wound Treatment (Physiotherapy)

Physical methods are doubtlessly indicated for the treatment of both fresh and suppurative wounds as well as accompanying muscular atrophy, paresis and paralysis, restricted joint movement, and retarded consolidation of fractures. Soon after trauma, physical methods combined with initial surgical treatment and chemotherapy effectively control residual microbial contamination of wounds and prevent development of infection.

Wounds undergoing healing, in the dehydration stage (the second week following trauma), would best be irradiated by erythemic doses of ultraviolet rays, which promotes greater success in infection control, improvement of circulation, and acceleration of epithelialization.

When wounds are sluggishly granulating, it would be useful to employ alternating longitudinal-transverse electrophoresis with 10 percent potassium iodide solution each day for 10-12 days, which noticeably improves circulation in the floor and walls of the wound and promotes activation of granulations; ultraviolet radiation sessions using small doses (not more than half a dose) are also effective.

Physical treatment methods are extensively indicated when preparing extensive granulating wounds for application of secondary sutures or dermatoplasty. It would be unsuitable to treat extensive granulating wounds for a long time by physical methods alone, without surgery (without secondary sutures or secondary dermatoplasty).

In order to accelerate epithelialization of slowly healing wounds of small size, we can employ ultraviolet radiation in suberythemic doses each day or every other day in combination with paraffin or paraffin-oil dressings.

During the recovery period therapeutic gymnastics are performed in parallel with paraffin and mineral wax therapy of joint areas to promote faster and fuller recovery of movement in the joint, especially the knee and foot. Phonophoresis with thyrocalcitonin can be employed to stimulate reparative regeneration of bone.

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Anaerobic Infection

Anaerobic infection or, as it is often called, gas gangrene is a very serious complication of the wound process elicited by anaerobic *Clostridium* (*Cl. perfringens, Cl. oedematiens, Cl. septicum, Cl. histolyticum,* and more rarely *Cl. sordelli, Cl. pallax,* and others).

Associations of anaerobes with aerobes, especially *Proteus*, aggravate the course of infection and increase mortality. The pathogenic properties of anaerobes are also intensified by some strains of *Staphylococcus* and *Streptococcus*.

Anaerobes have been noted in 95.1 percent of war wounds, but just penetration of agents into the wound is not enough to initiate anaerobic infection. The disease develops only when unfavorable general and local conditions are present. Anaerobic infection develops most often and swiftly in wounds containing large amounts of dead and dying muscle, when deep cavities, pockets, and foreign particles are present, and when circulation in the injured limb is impaired. All of this may occur in fractures typified by large numbers of fragments, excessive crushing of soft tissues of the limbs and torso, prolonged application of a blood-stopping tourniquet, late and poor initial surgical treatment of the wound, and poor immobilization for traveling. Considerable blood loss, traumatic shock, and exhaustion promote development of disease.

The frequency of anaerobic infection varied during the Great Patriotic War from fractions of a percent to 6 percent and higher (D. A. Arapov, 1950).

The pathogenesis of anaerobic infection has not been studied fully yet. In the first hours, and more rarely, days after trauma, bacteria entering the wound in favorable conditions multiply and spread through intercellular spaces and by means of blood and lymph vessels.

The second phase is toxic: Specific toxins and enzymes which have a pathological influence on muscle tissue, causing it to break down and putrefy, are produced through the vital activities of anaerobic bacteria or associations of anaerobes and aerobes. In turn, presence of large quantities of dead tissues in the wound creates conditions favoring reproduction of bacteria; tissue respiration is impaired, the permeability of vessels rises, and edema in the injured limb rises dramatically. When anaerobic infection is caused by *Cl. perfringens*, a large quantity of gas is formed in subcutaneous fatty tissue. Tissue breakdown by enzymes goes on to the cellular level, which is accompanied by formation of nonspecific toxic products.

Histological changes in tissues manifest themselves by the signs of tissue death in the absence of reactive phenomena. When parenchymatous organs undergo degeneration, death may occur due to poisoning by specific and nonspecific toxins (O. A. Levin, 1951).

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The clinical pattern: The clinical pattern of anaerobic infection is distinguished by great diversity, but in all cases we observe necrosis of tissues in the wound, edema in the limb, and sharp pains; formation of gas in subcutaneous fatty tissue and pallor or marbling of the skin are possible (Table 5).

The general phenomena usually include a dramatic rise in body temperature and breathing disturbances, pulse becomes rapid, filling of the heart is poor, and jaundice phenomena are possible; the patient is depressed or aroused, and his sleep is impaired or absent. A sharp drop in hemoglobin and erythrocytes is noted in the blood. The leukocyte count may be normal, but microbial phagocytosis is depressed or absent. The function of kidneys and other parenchymatous organs suffers.

Table 5. Local and General Symptoms of Anaerobic Infection (From D. A. Arapov, 1972)

Stage	Symptoms	
	Local	General
Early stage of restricted gas phlegmon	1. Pain in wound 2. Lifeless dry wound with dirty-grey incrustation 3. Dermal edema only about wound, with jaundiced hue	Mild toxemia, tachycardia in the presence of subfebrile temperature, moderate arousal, poor sleep, dryness of tongue root
Stage of progressive growth in widespread gas phlegmon	1. Symptom of shift in pains 2. Growth in edema and gas formation 3. Wound lifeless, dry, muscles edemic and everted 4. Jaundiced hue widespread. Bronze spots appear around wound	Toxemia. Insomnia. Dry, coated tongue. Low arterial pressure. Pulse rapid, weak, soft at 38-39°C. Heart tone dull. Increased anemia. Euphoria in severe cases
Gas gangrene stage	1. Absence of peripheral pulse on limb 2. Absence of pains and loss of sensitivity	Intense toxemia. Insomnia. Low arterial pressure. Dull tones. Thready pulse. Severe anemia. Inhibition or euphoria.

[Table continued on following page]

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	3. Further growth in edema and gas formation, latter moving to torso 4. Wound lifeless, dry, edemic, with everted margins 5. Bloody, suppurative discharge from deep in wound	

Early symptoms of anaerobic infection can include arisal of significant pain in the wound, the feeling that soft tissues are pushing apart, and revelation of significant and increasing edema of the limbs coupled with change in pulse and respiration (A. V. Mel'nikov, 1945; A. Lepukaln, B. Shtern, 1946; A. N. Berkutov, 1955, 1972, etc.).

Arisal of tissue crepitation indicates a far-gone process.

Prevention of anaerobic infection consists of the following set of mandatory integrated measures: Early and radical initial surgical treatment of the wound, early administration of polyvalent antigangrene serum and, just as early, chemotherapy, to include antibiotics.

Preventive serum treatment should be performed in relation to wounds involving considerable crushing of muscles, and in relation to splintered compound and gunshot fractures, especially when contaminated by foreign particles and dirt. The preventive dose of antigangrene serum is 30,000 IU [international units]. Serum is injected intramuscularly as soon as possible following trauma or wounding. Before injection it is diluted in a triple quantity of physiological solution. Before injection of the serum the patient's sensitivity to foreign protein is determined by means of a skin test with serum diluted to 1:1,000. At the same time it should be kept in mind that prevention of anaerobic infection depends mainly on the quality of initial surgical treatment, and not on administration of serum. In recent years the preventive effect of injecting serum has been placed under doubt. The decisive role belongs to early rescue of victims, good immobilization for traveling, and early initial surgical treatment combined with sensible postoperative care of the wound.

V. N. Mel'nikov, N. I. Mel'nikov, and K. S. Yenikeyeva (1971) emphasized that as with administration of serum, antibiotics do not solve the problem of preventing anaerobic infection, but in combination with radical surgical treatment of wounds they can reduce the number of anaerobic infection cases. Anaerobic bacteria are most sensitive to penicillin, ampicillin, tetracycline, erythromycin, lincomycin, and ristomycin, while other antibiotics are less effective or entirely ineffective.

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Treatment: When anaerobic infection is diagnosed, patients must be processed separately and then isolated. Surgical intervention requires not only extensive dissection of tissues but also excision of all injured tissues and removal of foreign particles to the extent possible. In the presence of gashes, fascial sheaths and muscle masses must be extensively dissected longitudinal to the injured segment of the limb. Wounds are packed loosely with tampons. The tampons should be wetted with hypertonic table salt solution, A. V. Vishnevskiy's oil-balsam emulsion, or emulsions containing sulfanilamides. When vital indications are present, the limbs of especially severe casualties must be amputated as high up as healthy muscles. A tourniquet is not applied to the amputated limb.

In the postoperative period patients with anaerobic infection require constant observation, intensified protein and carbohydrate nutrition, and vitamin therapy. Detoxification therapy must be performed simultaneously with surgical treatment in order to dilute and eliminate toxins: The casualty is given 400 ml 4 percent sodium bicarbonate solution, 5 percent glucose solution, and physiological solution (up to 2-3 liters fluid per day and more). Provision of large quantities of fluids in the presence of anaerobic infection also reduces blood viscosity and thus improves circulation.

Serum therapy and antibiotic therapy are a sensible addition to surgical treatment. Antigangrene serum is infused intravenously dropwise at large doses (150,000-200,000 IU per day). The serum must be diluted in a fivefold volume of physiological solution. A switch could be made to intramuscular injection toward the end of treatment. This makes it possible to keep the anatoxin titer in the body at a sufficiently high level. N. F. Dudko and N. Ye. Sinarskiy recommend administering *Cl. perfringens* anatoxin at a dose of 45,000 AU together with donor blood. A highly purified anatoxin has recently been obtained (G. F. Shemanova et al., 1966) which, if the indications permit, can be given early to patients, especially those with edemic (toxic) and mixed forms of anaerobic infection.

A triple anatoxin consisting of purified concentrated anatoxins of *Cl. perfringens* and *Cl. oedematiens* combined with native tetanus anatoxin has been developed and experimentally tested; aluminum phosphate and ekmolin are used as the vehicle (A. N. Sheyerson, 1957). Other complex anatoxins are known as well.

Blood transfusions are useful only in small doses--100-250 ml every 1-2 days during the recovery period with the goal of blood substitution and stimulation of the body in the event of a rapid drop in erythrocyte and hemoglobin count. Larger blood doses are contraindicated because liver functions may be disturbed (D. A. Arapov, 1950).

During the Great Patriotic War of 1941-1945 the following antiseptics were used most often to treat wounds exhibiting anaerobic infection: Chloramine, hydrogen perioxide, potassium permanganate, Vishnevskiy's ointment,

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synthomycin emulsion, Peruvian balsam, and so on. Treatment results were approximately the same. In our opinion irrigation of wounds for 3-5 days with antiseptic liquids combined with the use of sulfanilamide dressings and directed antibiotic therapy is the most indicated. When providing antibiotic therapy, consideration should be made of the dynamics of not only the anaerobes but also the aerobes in the wound or, more precisely, their associations. Apparently the most effective antibiotics would be ones with a broad spectrum of action, and their combinations.

Proper immobilization of the damaged limb by application of unpadded circumferential "openwork" or bridge-type plaster casts has great significance.

Thus anaerobic infection requires integrated therapy, in which surgery has the dominant role.

Tetanus

Tetanus is an extremely severe infectious complication of open injuries, and it is elicited by *Clostridium tetani*. It is easier to prevent tetanus than to treat it. Tetanus mortality continues to be high (28-40 percent). The disease may arise with wounds of any nature, dimensions, and depth, if *Cl. tetani* happens to settle in the wound. Its vital activities produce toxins that injure cells of the central nervous system. The incubation period lasts from several hours to 35 days and more.

Toxins--tetanospasmin and tetanolysin--play the principal role in the pathogenesis of tetanus. Enzymes produced by tetanus bacteria (proteases, fibrinolysin, and others) promote spread of the toxins. The following is the most probable hypothesis for movement of the neurotoxin--tetanospasmin: The toxin is adsorbed by motor neurons, and during the incubation period it moves along the axial cylinders from the focus of infection to the spinal cord, where it invades cells in the anterior horns. Another part of the toxin is conveyed by blood or lymph, it adsorbs to motor nerve endings, and it also travels along the nerve trunk to cells of the anterior horns of the spinal cord and the motor nuclei of the brain stem. The toxin's action upon the spinal cord causes muscular rigidity, local or generalized; invasion of centers in the medulla oblongata and the pons Varolii elicits clonic spasms (V. N. Mel'nikov et al., 1971).

Man does not possess natural immunity to tetanus toxin. Injection of inactivated toxin creates a high immunity to tetanus, which depends on accumulation of anatoxin in blood.

Clinical pattern: The first clinical symptoms of tetanus are awkwardness and stretching pains in the injured limb, pains in back muscles, the sides of the rib cage, and muscles of the abdominal wall and epigastral region, twitching of muscles in the vicinity of the wound, difficulties in opening the mouth and chewing, an increase in tendon reflexes, and arisal of

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pathological reflexes on the side of injury. It becomes difficult to bend the head forward, and photophobia and insomnia appear. Attention should be turned to these symptoms when sorting the patients, so that tetanus victims could be revealed and treatment could be started early.

Doubtless symptoms of tetanus include a sharp rise in body temperature (up to 39-42°C), profuse sweating, spasms of chewing and facial muscles, sharp spasm of back and occipital muscles coupled with backward flexing of the head (opisthotonos), and difficulty in swallowing and breathing; breathing arrest is possible.

Prevention: Early and radical initial surgical treatment of the wound is required. Moreover all victims with open wounds that had not been previously immunized must be given subcutaneous injections of tetanus serum (3,000 IU to adults and 1,500 IU to children) and tetanus anatoxin (1 ml to adults and 0.5 ml to children). The anatoxin is given again at a dose of 0.5 ml 30-40 days later. Victims that had been immunized against tetanus are given anatoxin alone (0.5 ml).

Treatment: Serotherapy--administration, under anesthesia (nitrous oxide) fluorothane), of large one-time doses of tetanus serum (50,000-200,000 IU to adults, 20-000-80,000 IU to older children, and 5,000-20,000 IU to infants) as early as possible in the first days.

Toxin circulating freely in the blood could be complete neutralized by one-time administration of serum in moderate doses not exceeding 200,000 IU. The serum should be administered both intravenously and intramuscularly, simultaneously. The serum is infused intravenously with physiological solution (250 ml). The serum is administered for 2 days in a row, reducing the dose on subsequent days by a third. Intralumbar and suboccipital injection of the serum is not permitted.

Three administrations of adsorbed tetanus anatoxin (1 ml each time) are mandatory in the acute period of illness.

Medicinal treatment must be accompanied in parallel by repeat surgical treatment of wounds (under anesthesia), removing all foreign particles and ensuring good drainage. Subsequent dressings are applied under anesthesia; the wounds and sutures are flushed several times with hydrogen peroxide, hypertonic solution, and proteolytic enzymes. Amputation is indicated in the presence of extensive limb crushing.

Anticonvulsive therapy is the basis of modern integrated tetanus therapy. The nature, extent, and means of such therapy depend on the severity of tetanus. We distinguish between four degrees of tetanus severity today: Mild (degree I), moderate (degree II), severe (degree III), and very severe (degree IV).

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In the mild form of tetanus the patient's condition is moderately severe, muscles are rigid, convulsive attacks are rare and weak, trismus is mild, sweating is moderate, and there are no breathing disturbances. In these cases a neuroplegic mixture of the following composition is injected intramuscularly two-three times a day in the first few days: 1 ml 2.5 percent aminazin solution, 1 ml 2 percent promedol solution, and 2 ml 2.5 percent pipol'fen solution. Cardiac agents are indicated: Cordiamine, corglycon. Also indicated are systematic infusions of 40 percent glucose solution (40-60 ml per day) with insulin, and chloral hydrate in enemas. In subsequent days tableted phenothiazine preparations (dimedrol, deparkin, and so on) and barbiturates (luminal, barbamil, and others) are given, combining them with administration of chloral hydrate, glucose, and cardiac agents.

In the presence of moderate tetanus the overall condition is serious; spreading hypertonia of muscles of the back and occiput, prelum abdominale, pronounced trismus, and moderate swallowing disturbances arise. The pulse increases to 120-130 beats per minute, and chronic convulsions are infrequent, without breathing impairment.

Treatment of this form of the disease must foresee systematic intramuscular injection of neuroplegic mixtures two-three times a day. Here are sample "cocktails" (from G. N. Tsybulyak):

	For Adults	For Children Older than 5 Years
Aminazin 2.5%	1.5-2 ml	0.5-0.75 ml
Promedol 2%	1-1.5 ml	0.5-0.75 ml
Dimedrol 1%	2-3 ml	1-2 ml
Scopolamine 0.05%	0.5-1 ml	0.25-0.5 ml

The patient is additionally given barbiturates perorally or chloral hydrate in enemas, cordiamine, and corglycon.

The patient's overall condition is very severe in the presence of the severe form of tetanus. Chronic-tonic convulsions of muscles of the torso, neck, and rib cage are observed. Cyanosis of skin surfaces and respiratory insufficiency are pronounced. The pulse is rapid and intense. Body temperature attains 39°C. Swallowing disturbances are pronounced. In such forms the neuroplegic mixture is administered more frequently (three-four times a day). The composition of the "cocktails" and the doses of the medicinal agents are as follows:

	For Adults	For Children Older than 5 Years
Aminazin 2.5%	2-2.5 ml	0.75-1.0-1.5 ml
Promedol 2%	1-1.5 ml	0.5-1.0-1.5 ml
Pantopon 2%	1-1.5 ml	--
Dimedrol 2%	2-3 ml	1.0-1.5 ml
Scopolamine 0.05%	0.5-0.7 ml	0.25-0.5 ml

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Massive administration of neuroplegic drugs to extremely old patients is contraindicated.

In addition to the "cocktail," patients with the severe form of tetanus are given dissolved barbiturates (5-10 percent solutions, 100-300-500 ml each), or chloral hydrate is given in an enema (3-5 percent solutions, up to 50-150 ml). Use of cardiac agents, antibiotics, and vitamins is doubtlessly indicated.

In the presence of extremely severe tetanus we observe opisthotonos, the duration of convulsions is longer, the pulse attains 180 beats per minute, it becomes light, and heart filling is poor. Progressive hypotonia, pronounced dyspnea, and laryngospasm are present; development of apneic crises and convulsive asphyxia is possible.

The treatment of such patients requires intravenous dropwise infusion of relaxants, 2 percent barbiturate solution, and neuroplegic mixtures.

If the intravenous infusion apparatus is temporarily nonfunctional, ditiline or listenon (myorelaxin) must immediately be injected intramuscularly, and later intravenously, from previously prepared syringes in order to suppress life-threatening convulsions. Cardiac agents (cordiamine, caffeine) are injected in parallel, and neuroplegics are repeatedly administered, since frequent attacks of convulsions creating a threat of breathing arrest must be curtailed. Alternation of lytic mixtures and hexenal is effective.

When stable respiratory insufficiency arises, chronic spasms of long duration are present, and the bronchotracheal system is obstructed by accumulations of moisture or aspirated food, an emergency tracheostomy is indicated, making adequate artificial ventilation of the lungs possible.

Cytiton is injected in response to reflex respiratory arrest in especially severe patients (for adults, 0.5-1 ml into the vein or intramuscularly). The injection should be repeated after 15-30 minutes.

When degree IV tetanus is present it is especially important to fight pulmonary complications and support the functions of the cardiovascular system, and to administer energy-rich substances and fluids (blood, plasma, protein hydrolysates, glucose, alcohol, salt solutions). The patient takes liquids through a probe introduced through the nasal passages (beef broth, strained soup, soup stock, fruit gels, juices).

When hyperpyrexia is observed (body temperature above 38.5-39°C), parenteral administration of anagin, pyramidon , and pyrobutol and cooling by physical methods (ice bags on the head and the inguinal region) are indicated.

In exceptional cases, when intense and frequent convulsions of degree IV tetanus cannot be eliminated with sedatives and neuroplegic drugs, curare preparations are administered (d-tuborcurarine chloride, diplacin, paramyon, phentanil, and so on) in combination with artificial lung ventilation.

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After adequate spontaneous breathing recovers, administration of the neuroplegics and barbiturates is continued so that intense convulsions would not begin again.

All tetanus patients, irrespective of the degree, require constant observation and qualified care. Functions of the breathing organs and cardiovascular system (heart tones, pulse, pressure, EKG data), the kidneys, and the liver, and the blood composition must be monitored.

To the extent possible, specialists--reanimatologists or anesthesiologists--must provide treatment in all stages of tetanus.

Tetanus treatment departments must be supplied with special anesthesiological apparatus, respirational and other equipment, special instruments, and a sufficient quantity of medicines and bandaging materials. After dressings are applied, instruments should be soaked in 2 percent soda solution, rinsed in running water, soaked for 3-6 hours in a strong antiseptic solution, and only after this can they be boiled for not less than 1 hour.

The wards must be places of total peace and quiet, and subdued light. Meticulous patient care has great significance.

Antibiotics with a broad spectrum of action should be administered only to prevent and treat general and local complications--suppuration of wounds, sepsis, pneumonia, and so on. Antibiotics are not effective in tetanus treatment because they do not have an influence on tetanus toxin circulating in the blood and in other body fluids.

It has now been demonstrated with a large amount of clinical data that a significant proportion of tetanus patients are transportable (including in the acute period of disease) if they are conveyed by special transportation and are accompanied by teams of specialists--anesthesiologists or reanimatologists. While en route, the patients are given alcohol, neuroplegic drugs, and myorelaxants in combination with artificial lung ventilation. It would be suitable to concentrate casualties with tetanus in one of the specialized hospitals of the hospital collection center; the hospital should be outfitted with special equipment and medicines, and it should be staffed by experienced physician-reanimatologists or anesthesiologists, and specially trained secondary medical personnel.

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CHAPTER 5

THERMAL BURNS

Thermal burns have extremely important significance in the structure of the pathology of a modern nuclear missile war. Thus there were about 100,000 burn victims in Hiroshima and Nagasaki after the American troops used nuclear weapons against those Japanese cities.

In 95 percent of the cases they were primary burns, resulting from direct exposure of exposed portions of the body to light radiation, and in 5 percent of the cases they were secondary burns, resulting from ignition of clothing or caused by flames from burning objects (Miller, 1956).

According to the data of a number of researchers the quantity of burn victims (including those with combined injuries) may attain 65-85 percent of all medical losses, in which case about 30-40 percent will receive extensive and deep burns (A. A. Vishnevskiy, M. I. Shrayber, 1968; Ye. A. Polyakov, B. M. Khromov, 1969).

The severity of burn trauma depends on many factors--location, age, general condition of the victim, and so on. But two factors--the depth and area of injury--have especially important significance.

The burn classification proposed by A. A. Vishnevskiy and M. I. Shrayber and adopted by the 27th All-Union Congress of Surgeons has enjoyed the greatest acceptance in our country.

According to this classification we distinguish between four degrees of tissue injury: Degree I is typified by hyperemia and edema of the skin, degree II is characterized by vesiculation, and degree IIIA is characterized by injury to the dermis, with surviving islets of epithelium in the vicinity of dermal adventitia (sebaceous and sweat glands, hair follicles). The growing layer is only partially injured with degree IIIA burns, and for this reason independent epithelialization of the burn is possible under favorable conditions. A degree IIIB burn is typified by necrosis in all dermal layers, and degree IV is characterized by injury to not only the skin but also the deep-lying tissues (subcutaneous tissue, muscles, bones).

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Degree I, II, and IIIA burns are categorized as superficial burns. Degree IIIB and IV burns are deep burns. A combination of different degrees of burns can usually be observed.

It is often impossible to determine the depth of injury in the first hours and even days after burning.

In a number of cases areas of necrotic skin can be revealed by change in color (a dead, pale color, or charring) and compaction of tissues coupled with manifestation of a pronounced pattern of subcutaneous veins. Sometimes injured skin in the vicinity of major joints gathers into folds. Pain and tactile sensitivity is lost.

In a number of cases the medical history can help in better determination of the depth of tissue injury: When the injurious agent is high in temperature and its time of contact with the skin is long, deep burns usually result. Sometimes linear sections of injured skin, made to reveal "spot" hemorrhaging, are used to diagnose depth of injury. But in many cases we can reveal the true depth of a burn only after 5-7 days, and sometimes even later. This is explained by the fact that in addition to initial necrosis of tissue arising at the time of action of the injurious agent, secondary necrosis usually develops during subsequent days in the vicinity of the burn owing to disturbance of tissue nutrition (thrombosis of small vessels, their crushing by exudate).

For practical purposes it is important to know, at least tentatively, the dimensions of the total burn area and, separately, the area of deep injuries. The dimensions of the burn wound are commonly expressed as percentages of the total skin surface.

The following methods for determining burn area are the most widely accepted today.

The rule of "nines": For adults, the surface of the head and neck make up 9 percent of total body surface, the surface of one upper limb is 9 percent, the front surface of the torso (chest, abdomen) is 18 percent, the back surface of the torso is 18 percent, the surface of one lower limb is 18 percent, and the surface of the perineum and external genitalia is 1 percent of total body surface.

Burn area on a child can be computed with Table 6.

Palm measurement: The area of the adult palm is about 1 percent of total skin area. The area of injury can be estimated by comparing the area of the palm with the area of burned body surface. This method is used with restricted burns or less than total injuries. With restricted burns, the palm is used to measure the burn area, while with subtotal burns the area of uninjured portions of the body is determined, and the percent skin injury is obtained by subtracting the resulting figure from 100 percent.

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Table 6. Determination of Burn Area for Children

Body Parts	Area, Percent, Depending on Age		
	Up to 1 Year	1-5 Years	6-12 Years
Head	21	19	15
Upper limb	9	9	9
Torso, front or back	16	16	16
Lower limb	14	15	17

Vilyavin's system can also be used to measure burn area. His system involves two silhouettes (front and back) of a person of medium height, reduced tenfold and superimposed over a 5-millimeter grid. Areas corresponding to surfaces suffering burn injury are cross-hatched, and then, assuming that every square equals 25 square centimeters of skin surface, the total burn area is computed in square centimeters and converted to a percentage using a table attached to the chart. This method can be used only in specialized hospitals.

Inasmuch as total burn area and depth of injury define the patient's condition, they must be clearly reflected in the diagnosis. The location of injury and the agent causing the burn must be noted as well. When deep burns are present (degree IIIB-IV), their area is indicated separately. For example: Degree II-III burns of the face and front surface of the torso caused by flames, 22 percent of the body surface (IIIB--4 percent).

Clinical Pattern of Burn Disease

Nonfestering degree II burns heal in 7-12 days without scarring. In the event of suppuration wound healing takes longer, and a scar may form in a number of cases. With degree IIIA burns the wound undergoes epithelialization due to the epithelial elements of sebaceous and sweat glands, hair follicles, and the surviving epidermal germinative layer.

With degree IIIB and IV burns, independent healing takes a long time, and it is possible only within restricted limits. If the area of degree II-III burns exceeds 10-15 percent of the body surface, the victim develops burn disease.

The course of burn disease is delineated into periods of shock, acute burn toxemia, septicemia, and reconvalescence.

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A unique feature of the course of burn shock is its duration--24-48-72 hours. Burn shock is characterized by disturbances in functions of the nervous, endocrine, and cardiovascular systems, and disorders of all forms of metabolism and of the functional state of internal organs.

Regional (hepatic, renal, intestinal) and peripheral circulation decreases sharply first. Hemodynamics undergo centralization to ensure a high blood supply to the heart, brain, and lungs. Microcirculation in the burn wound ceases or declines dramatically, and it becomes significantly altered in all organs and tissues. This is the reason that mixed hypoxia develops, leading to intense liberation of biologically active compounds. Intra- and extracellular electrolyte and water balances are disturbed simultaneously. Pronounced plasma loss from burned surfaces and transudation of plasma into interstitial spaces are observed. Tissues undergo hyperhydration first in the vicinity of the burn and then in areas away from it. The volume of circulating blood and the minute heart volume drop progressively.

Disturbance of water and electrolyte metabolism is accompanied by hyponatremia and hyperkalemia. Erythrocytes undergo heightened breakdown, and hemoconcentration occurs: The erythrocyte count and the hemoglobin level increase dramatically, the hematocrit rises, and the level of residual nitrogen and sugar in the blood often increases. The vital capacity of the lungs drops constantly, blood oxygen saturation declines, tissue oxygenation decreases, incompletely oxidized products accumulate, the concentration of lactic and pyruvic acids rises, and respiratory and metabolic acidosis develops.

In the shock stage we can note significant changes on the part of the endocrine system, particularly the adrenal cortex. Although the level of hormones increases in the adrenal cortex by two to four times in the presence of burns, when deep burns are present over 20-30 percent of the body surface their level is too low to satisfy the body's greater needs. Relative adrenal insufficiency develops. This pertains especially to children up to 2 years old, in whom the level of steroid hormones rises insignificantly in the blood.

The clinical symptoms of burn shock, especially mild and moderate shock, are not always sufficiently pronounced at first. In the first 4 to 6 hours following burn injury, relative well-being persists temporarily due to spasm of peripheral vessels and centralization of hemodynamics. Arterial pressure remains within normal limits, and its decline is in general a later sign of burn shock.

Temperature is low, though sometimes it remains normal. The most constant and typical sign of burn shock is oliguria and, in extremely severe cases, anuria. Dyspeptic disturbances (vomiting, thirst) are often observed.

The course of burn shock depends on the depth and area of burns, the victim's age, and presence or absence of accompanying diseases, and it worsens if

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the burn victim had suffered additional trauma (cooling, processing of the burned surface, late and irrational antishock therapy). Burn shock proceeds much more seriously when burns are present in the respiratory tract.

Acute burn toxemia develops as a result of the body's intoxication by the products of protein decomposition, toxic substances passing into the body from burn wounds, and bacterial toxins.

The beginning of the period of acute burn toxemia coincides with arisal of fever (the 2d or 3d day after burning), normalization of diuresis, stabilization of arterial pressure, and a decline of hemoconcentration. The end of the second period coincides with appearance of clinically expressed suppuration of burn wounds.

The expressiveness of toxemia depends on the depth and area of skin injury as well as on the nature of necrosis (in the presence of deep burns). In the presence of moist necrosis intoxication is more strongly pronounced.

When injuries are superficial and wounds do not undergo pronounced suppuration, burn toxemia may be superceded by a period of reconvalescence, without the septicemia period.

Toxemia lasts from 2 to 14 days and more depending on the burn area, especially the area of deep injuries, and the nature of necrosis. In the presence of moist scab necrosis the period of acute burn toxemia is much shorter than in the presence of dry necrosis.

Fever, tachycardia, poor appetite, occasional vomiting, and intoxication of the nervous system manifesting itself as insomnia, occasional delirium, and muscle twitching are typical of the clinical pattern of acute burn toxemia. If inhibitory phenomena prevail in the central nervous system, the victim develops somnolence going as far as arisal of a comatose state.

Leukocytosis grows in peripheral blood, with the formula shifting left, and hypoproteinemia develops together with dysproteinemia, associated with continuing generalized decomposition of protein and impairment of its synthesis.

The period of burn septicemia is a direct continuation of the second period. In this case the toxemic phenomena are compounded by phenomena associated with suppuration and rejection of the burn scab.

The clinical pattern is typified by remittent purulent-resorptive fever, insomnia, poor appetite, and weight loss. High leukocytosis is noted in the blood, with the formula shifting to the left, and anemia, hypoproteinemia, dysproteinemia, and bacteremia increase. In severe cases septicemia is complicated by arisal of pyemic foci and development of sepsis.

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Deep and extensive injuries, old age, and unsensible therapy cause the course of septicemia to become serious.

Complications

Burn disease is often accompanied by various complications (pneumonia, hepatitis, nephritis, nephrosonephritis, acute ulcers of the gastrointestinal tract). Functional changes in internal organs, which can later lead to severe organic damage, dominate in the early period following burning.

Burn emaciation is the most frequently encountered and most serious complication of burn disease. It arises in the 4th through 8th weeks of burn disease and lasts from several months to 1-1.5 years, and it is accompanied by growth in hypo- and dysproteinemia.

The clinical signs of burn emaciation include cessation of repair processes and progressive necrosis in wounds leading to their breakdown and deepening, and dramatic weight loss going as far as cachexia. Burn emaciation often leads to the victim's death.

In addition to the complications listed here, we can observe lymphangitis and lymphadenitis, erysepalous inflammations, purulent congestions, phlegmons, and arthritis. Disfiguring shrinking scars and contractures and trophic ulcers are encountered among the most severe burn victims.

Injury by Light Radiation and Burning Mixtures

Burns of the Skin by Light Radiation from a Nuclear Burst

Light radiation can cause burns either as a result of direct exposure of exposed portions of the body, or indirectly due to ignition of clothing, buildings, and so on. This is why we commonly distinguish between primary and secondary burns by light radiation. The latter are analogous with ordinary burns caused by flames.

The main cause of primary burns is the action of predominantly visible and infrared rays, liberated during the second phase of light radiation, on the skin. In this case the skin absorbs the radiation; the energy of the latter transforms into thermal energy, promoting intense heating of tissues and, consequently, their thermal injury. Ultraviolet rays, which arise basically at the first phase of light radiation, do not have independent injurious action upon the skin. The reason for this lies in the fact that the first phase of radiation is extremely short, especially when the power of the burst is low, and ultraviolet rays are quickly weakened as they pass through the atmosphere. Nevertheless, inasmuch as ultraviolet rays do produce greater biological effects than do visible and infrared rays, in some conditions, especially when the time of action of the first phase of a nuclear burst is longer (this is true for the more-powerful nuclear weapons), they may intensify the injurious effect.

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Light radiation victims in Hiroshima and Nagasaki had primary skin burns for the most part. They were characterized by the most diverse depth and area of injury, which depended on the location of the victim at the time of the burst. Thus in a radius of up to 0.8 km from the epicenter of the burst the burns were extremely severe and lethal, burns of predominantly degree III were noted at a distance of up to 2 km, degree II-III burns dominated in the zone 2-3 km from the epicenter, and degree I-II burns dominated in the 3-4 km zone. The farther the victims were from the epicenter, the smaller was the burn area: At a range of 1.5 km burns of small area were encountered in 40 percent of the cases, while at a radius of up to 3-4 km they were encountered in 85 percent of the cases.

After explosion of atomic bombs in Hiroshima and Nagasaki (1945) the number of burn victims climbed to 100,000. Burns were the principal form of injury for 65 percent of the victims, and the cause of death for half of the dying victims was severe burns.

Despite the fact that primary burns are typified by varying depths and area of injury, they nevertheless do have a number of features distinguishing them from conventional (household) thermal burns: As a rule they arise on exposed portions of the body facing the burst--that is, they are "profile" burns; the configuration of the burn often corresponds to the outlines of objects standing in the way of the light radiation, and the depth of injury is small (degree I, II, IIIA). This can be explained by the fact that the quantity of thermal energy acting upon a unit area per unit time is so great that the skin temperature grows quickly, resulting in severe burns, going as far as charring, but ones that are relatively superficial (Hatano, 1964).

Because of these unique features of the action of light radiation, we also note sharp demarcation of burns, in relation to both area and depth of injury. In this case the scab is dense and uniform in depth, and the underlying dermal layers remain undamaged.

Blood vessels within them do not lose their capability for the usual vascular reactions, while epithelial cells retain their ability to proliferate. Vascularization of deep dermal layers and survival of islets of the germinative layer and of the epithelium of dermal adventitia promote relatively quick delimitation and rejection of necrotic tissues and complete epithelialization of the wound surface.

If they did not get infected, the primary burns of casualties in Hiroshima and Nagasaki usually healed in the first 2-3 weeks without any sort of complications. But when the victims were not provided the necessary care, treatment, and nutrition, the absolute majority of the burns were infected, and in such cases it took the victims a long time to recover.

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Because the spectrum of light radiation from a nuclear burst contains ultraviolet rays, areas of pigmented and depigmented skin form on burned areas as they heal. This is why persons who had been burned by an atomic bomb explosion were sometimes left with a quite unique, typical skin color--the "Hiroshima mask."

Keloid scars develop in the vicinity of burn scars in a significant percentage of the cases.

As the power of the nuclear burst increases, the radius and time of action of light radiation grow. Consequently the quantity of radiation energy required to cause burns of a particular degree of severity increases. Because the time of action of light radiation increases, a person within the zone of its influence could change his orientation to the luminous area of the burst several times. Thus the conditions for formation of profile burns would be absent. Considering the variations in time of action of radiation on different portions of the skin, victims would apparently more often exhibit combinations of different degrees of burns.

Thus primary burns arising in response to explosion of large nuclear weapons would differ little in depth of injury from secondary burns.

Injury by Burning Mixtures

Among burning mixtures, napalm, which is a semiliquid viscous substance obtained by adding a special thickening agent to gasoline, will be used more frequently than others for military purposes. The burning temperature of napalm is within 800-1,000°C. Bombs, missiles, mines, and even hand grenades can be filled with napalm. During the wars in Korea and Vietnam the American troops employed mass napalm strikes predominantly.

In an area subjected to a napalm attack, people are injured not only by the burning mixture but also by carbon monoxide produced by its combustion and by heated air. In distinction from light burns, napalm burns arise as a result of prolonged action of the thermal agent upon the skin. These burns are unique because of the high temperature of burning napalm and the lengthy time of its contact with the skin. Prolonged action of thermal energy promotes heating of tissues to a great depth, as a result of which the conditions are created for arisal of very deep burns.

In the first hours a dense scab appears at the place of the burn, and pronounced tissue edema occurs about its periphery. Later, following a necrotic course, the scab drops into the infiltrate surrounding it, and it remains in this state for a long time without visible changes. Histological investigations have shown that tissue near the burned surface is in a state of necrobiosis. As the necrobiotic tissues are rejected a wound forms with profuse purulent discharge and undermined margins passing in the direction of the infiltrate. Healing of such a wound usually drags on for 2.5-3 months.

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Rough scars form at the place of a healed napalm burn, causing pronounced deformation of limbs and even the torso, followed by impairment of limb functions. The eyelids, nose, lips, and ears undergo deformation especially often. After the scar forms the skin becomes shiny, nodular, dry, bright red, and unyielding. The face assumes a mask-like form. Keloid scars, followed by disfiguration and development of severe contractures, form most frequently with napalm burns than with other forms of thermal injuries (L. N. Plaksin, 1967).

Use of burning mixtures as weapons predominantly elicits deep injury of tissues--degree IIIB and IV. Napalm usually affects exposed portions of the body.

Injuries to Organs of Vision by Light Radiation from a Nuclear Burst

Visual organs are injured in a nuclear burst due to the effect of light energy in the ultraviolet, visible, and infrared ranges. The following injuries are possible in this case: Temporary blindness (dysaptation); nuclear opthalmia (acute keratoconjunctivitis); eyelid burns; burns on the anterior portion of the eyeball;

burns of the ocular fundus (chorioretinal burns).

Temporary blindness arises as a result of the action of visible radiation, nuclear opthalmia is caused by ultraviolet radiation, and thermal injuries to the eyelids, the anterior portion of the eyeball, and the ocular fundus are elicited by visible and infrared radiation.

Temporary Blindness

Temporary blindness is defined as reversible impairment of all visual functions in response to the action of bright light sources. The experience of Hiroshima and Nagasaki demonstrated that blindness usually lasts only 2-5 minutes on a clear sunny day. At night, the time of blindness may reach 30 minutes and longer (Pearse, 1959). Blindness occurs immediately after the explosion, when bright light covers the entire field of vision. During this time the visual functions are inhibited, and successive images appear, taking the form of colored circles or flickering of colored flashes in front of the eyes. Some victims experience unpleasant sensations or painful phenomena, and eyelid spasms (V. L. Polyak, 1957). Irritation symptoms intensify in a brightly lit room and decrease somewhat in darkness. Soon the blindness symptoms begin to abate, and vision fully recovers.

"Nuclear" Opthalmia

Several hours after the nuclear burst, some victims in Hiroshima and Nagasaki began to experience pains in the eyes, dramatic photophobia, and tearing. This was accompanied by hyperemia and edema of the conjunctiva and eyeball,

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and sometimes clouding and ulceration of the cornea. It would have to be assumed that when nuclear bursts occur in the air, in the dense layers of the atmosphere, the number of casualties with nuclear opthalmia will be small, since with such bursts ultraviolet rays make up a relatively small percentage of the spectrum of light radiation, and they are intensively absorbed by the atmosphere. The possibility is not excluded that the incidence of nuclear opthalmia will increase with high-altitude bursts, in relation to which the proportion of ultraviolet radiation would grow significantly.

Burns of the Eyelids and the Anterior Portion of the Eyeball

These injuries will often arise simultaneously with facial skin burns. Light burns of the eyes have some distinguishing features in comparison with conventional thermal injuries elicited by flames, hot objects, and so on. Thermal factors usually injure the cornea and conjunctiva, while light radiation causes the greatest damage to the iris and conjunctiva, and the cornea is injured relatively rarely, only in response to significant light pulses (S. G. Sherashov, 1968).

An increase in the incidence of injuries to the anterior portion of the eyeball can be expected with low-power nuclear bursts, when the injurious pulse of light radiation will last for a shorter time than that of the blinking reflex (0.1-0.15 sec).

Burns of the Ocular Fundus

Chorioretinal burns are a new form of war injury to visual organs. They are observed at significant distances from the epicenter of a nuclear burst where burns do not arise on exposed portions of the body. This can be explained by the focusing properties of the eye's optical system. Owing to high concentration of thermal energy over a small area, coagulation occurs in retinal tissues--that is, they burn (B. L. Polyak, 1957). The effect chorioretinal burns have on visual functions depends on the severity of injury, its dimensions and, most importantly, its location on the ocular fundus. Burns in the vicinity of the optic disk are especially dangerous, since they can result in total loss of vision. A burn located in the vicinity of the fovea centralis causes formation of a central scotoma and, consequently, sharp impairment of visual functions.

Serious disturbances of vision can also be observed with injury to the maculopapullar nerve tract in the retina. But in realistic conditions most cases will involve burns of the peripheral areas of the retina, which as a rule would not elicit significant disorders.

A diagnosis of chorioretinal burns is made on the basis of subjective data and ophthalmoscopy. Ophthalmoscopic burns of the retina and choroid are predominantly round or oval, having distinct margins and a greyish blue

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or yellow color. Later, dark brown pigment begins to accumulate around the zone of coagulation, and by the 5th-10th days resorption of the coagulant begins. Scar formation usually ends by the end of the 3d week.

Retinal and preretinal bleeding is encountered in a number of cases (N. I. Mudretsov, V. M. Chernykh, 1964).

Thus in a nuclear war we can expect a significant number of victims with restricted and especially functional injuries to the organs of vision. The nature and scale of eye injuries will depend on the transparency of the atmosphere, the size of the pupil, the individual's orientation in relation to the burst, and the power and form of burst.

Burns of the Respiratory Tract

The usual causes of injuries to the respiratory tract are flames, heated air, toxic combustion products (in 95 percent of all cases) and, more rarely, superheated steam. Inasmuch as moist air is characterized by relatively greater heat conductivity, greater humidity promotes aggravation of thermal injuries of the respiratory tract. Inhalation of smoke significantly aggravates the course of the pathological process.

Clinical-morphological and experimental studies have produced certain ideas about respiratory tract burns. Sharp disturbances in circulation (vascular plethora, edema, and hemorrhaging) develop in the respiratory tract almost concurrently. Similar changes arise in alveolar tissue, apparently by a reflex mechanism, and diffuse bronchospasm develops concurrently. These are precisely the disturbances which subsequently play the main role in the course and outcome of the process. They may lead to rapid death of the patient or to massive pulmonary edema, and they may be responsible for progressive necrotic processes and development of profound inflammatory processes in the respiratory tract and lungs. Circulatory disturbances in the lungs play the decisive role in development of pneumonia, which is the most important cause of death among patients with burns of the respiratory tract a long time after injury. Diffuse bronchospasm in the early period of burn disease is the main cause of respiratory insufficiency in victims.

The symptoms of respiratory tract burns include pain in the throat when swallowing, cough, dry mouth, hoarseness, aphonia, dyspnea, and participation of auxiliary muscles in the breathing act; auscultation of the lungs reveals bronchial breathing and dry, diffuse crepitation. Despite this, respiratory tract burns often remain undiagnosed. This can be explained by the fact that the clinical pattern of injury is often diffuse, and symptoms of dermal burns dominate. But even in these cases, where the victim had experienced trauma in a closed space, with injuries occurring to the neck and face, and all the more so when examination reveals whitish necrotic spots in the mouth cavity and burned nasal hairs, there can be no doubt of the existence of respiratory tract burns.

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A severer course of burn shock, development of early pneumonia, and a severer later course of burn disease are typical of patients with respiratory tract burns.

The complex of antishock measures must include cervical vagosympathetic novocaine blockades using A. V. Vishnevskiy's method (25-30 ml 0.25 percent novocaine solution on each side). The blockade should be made in all cases of facial and neck burns, even in the absence of clinical signs of respiratory tract burns. When necessary, the novocaine solution can be introduced through burned skin.

It follows from the above that bronchospasm and disturbances in circulation in respiratory organs are the principal factors in the mechanism of respiratory tract burns. The high effectiveness of vagosympathetic blockade stems from its normalizing action on both factors.

Antishock transfusional therapy is provided to patients with respiratory tract burns in accordance with the general rules, but streamwise infusion of liquids into the bloodstream must be performed with great caution and in small volume, inasmuch as it can lead to development of pulmonary edema and the victim's death.

Inhalation of various medicines is broadly practiced in the treatment of respiratory tract burns. Aerosol introduction of medicinal preparations right into the respiratory tract is highly effective, inasmuch as it ensures immediate admission of medicines to the focus of injury and promotes relief of bronchospasm, elimination of painful sensations in the throat and larynx, liquifaction of thick, viscous secretions in the bronchotracheal system, improvement of its evacuation and, most importantly, prevention of inflammatory processes in the respiratory tract and lungs and their elimination.

Victims are given inhalational treatment with the GEI-1, an individual domestic electroaerosol generator specially developed and intended for treatment of respiratory tract burns.

Inhalational therapy is performed one to two times a day for 10-15 minutes in the course of 2-3 weeks.

Bronchospasm and edema of the respiratory tract and lungs is controlled by inhalation of 1 ml 1 percent dimedrol solution, 1 ml 5 percent ephedrine solution, and 1 ml 1 percent or 2 percent novocaine solution. Inhalation of hormonal preparations having pronounced broncholytic and antiinflammatory action and normalizing vascular permeability has the same objective (30 mg prednisolone, 125 mg hydrocortisone).

Inflammatory changes in the respiratory tract and lungs are treated by inhalation of antibiotics with a broad spectrum of action (oxacillin) mixed with necrolytic substances (hygroin, terrilitin).

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Diuretics (dichlothiazide, furosemide) are prescribed to burn victims for the fastest possible healing of face and neck burns and elimination of respiratory tract edema.

Treatment of Thermal Burns

Principles of General Treatment

Victims in a state of burn shock or with burns that could lead to burn shock must be placed in a specialized antishock ward, and they should be given a subcutaneous injection of 3,000 AU tetanus serum (Besredka's method) (if such injection had not been made earlier) and anatoxin as required. If the burn victim has dressings on, they are not removed.

When burns are present on the lower limbs or abdomen the victim is subjected to a bilateral paranephric novocaine blockade (A. V. Vishnevskiy's method) using warm 0.25 percent novocaine solution (80-100 ml on each side). When burns are present about the waist, novocaine can be injected through burned tissue after cleaning the injection location.

A Vishnevskiy bilateral cervical vagosympathetic blockade is made with 0.25 percent novocaine solution (40 ml on each side) in the presence of burns of the face, neck, respiratory tract, and rib cage.

Intensive transfusional therapy has the most important significance in the treatment of burn shock; it is directed at normalizing hemodynamic disturbances, replenishing plasma, erythrocytes, and protein, detoxification, and rectification of the acid-base and electrolyte balance and renal functions.

An adult victim is given intravenous infusions totaling an average of 4-5 liters of fluid per day--800-1,200 ml dextran, 500-700 ml plasma (or 100 ml 20 percent albumin), 300-600 ml 0.1 percent novocaine solution, 800 ml lactosol, 400 ml hemodes, 30 gm mannitol one or two times a day, 1,000 ml 10 percent glucose solution with 20 units of insulin, and 250-500 ml freshly citrated Rhesus-compatible blood of the victim's group.

Usually the victim is given 1,800-2,000 ml of fluids in the first 6 hours after admission. Then the rate of infusion decreases to 40-60 drops per minute, in such a way that the rest of the required fluid would be administered during the rest of the day.

In addition to cardiac agents (corglycon, strophanthin), the victim is given an intravenous injection of prednisolone (30-60 mg) or hydrocortisone (200 mg on the first day) depending on arterial pressure.

Novocaine blockades and intravenous infusions of novocaine normalize heightened permeability of capillaries and reduce plasma loss and vascular spasm.

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A permanent catheter must be introduced into the urinary bladder of the victim to permit registration of hourly diuresis.

To relieve pain, the victim is given an intravenous injection of 1 ml 2 percent promedol solution four times a day in combination with 1 percent dimedrol solution.

The victim must be allowed to breathe humidified oxygen periodically. On the 2d-3d days the patient is given the same quantity of liquids, or half, depending on whether or not hemodynamics and diuresis have normalized.

Therapy in the toxemic and septicemic periods is aimed at fighting intoxication, infection, and anemia, and at preventing various complications.

Transfusions of 250-500 ml of blood two or three times a week have important significance. In addition to blood, 250-500 ml plasma or 50-100 ml 10-20 percent albumin solution or 500 ml protein hydrolysates are transfused. Hemodes and neocompensan are used for detoxification purposes.

Administration of the following antibiotics is indicated: benzylpenicillin (sodium salt), 4-6 million AU per day or 4 million AU ampicillin, and 4 million AU oxacillin. Later, antibiotics are prescribed depending on the sensitivity of the flora, and in combination with antihistamine preparations (dimedrol, suprastin, etc.).

As the indications require, cardiac and pain relieving agents are administered to burn victims, and vitamins are systematically prescribed--A, B, B_2, B_6, B_{12}, C, and D.

Use of glucocorticoids (prednisolone, etc.) is indicated in the presence of burn emaciation.

Therapeutic nutrition is the most important element in the treatment of burn victims. The patient must receive 200-250 gm protein per day. The total calorie count of the daily ration must be up to 5,000 kcal. The menu includes cottage cheese, kefir, eggs, meat, fish, and fruit and vegetable juices. Food should be given in small portions four to six times a day. Serious patients would best be fed various high-calorie mixtures through a probe.

Hygienic maintenance and care of burn victims plays an important role. The wards must be spacious, bright, and well ventilated. Wet mopping of the wards, partial changing of bed linens, and ultraviolet irradiation of the wards have great significance.

Patients cannot be kept in purulent departments. Frequent turning of patients, rub-downs with camphor alcohol, replacement of soaked dressings and straightening of dislodged dressings, and engagement in therapeutic physical culture play an important role in preventing bedsores.

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Cleansing of the mouth, a reclining position, and breathing gymnastics are aimed at preventing development of various complications, mainly on the part of the lungs.

Principles of Local Treatment

Treatment of burn wounds has its unique features in every period of burn disease. Thus immediate covering of wound surfaces with slightly warmed ointment dressings is a necessary measure promoting quick recovery from a state of shock in relation to patients in shock. Initial cleansing of the wound surface is performed for this group of patients only during the time of the first change of dressings--that is, on the 3d-4th days after trauma.

When shock is absent and the victim's general condition is satisfactory, initial cleansing of the burn wound may be performed on the day of admission to the therapeutic institution. Before changing of the dressing, 1-2 ml 2 percent promedol solution is injected subcutaneously as an anesthetic.

Before beginning the cleansing of a burn wound, we determine the area and depth of injury and take several smears from different portions of the wound in order to clarify the nature of bacterial flora and its sensitivity to various antibiotics.

Cleansing of a burn wound involves cleaning the surrounding skin, irrigating the wound slightly with warmed antiseptic solution, opening large blisters at their bases and evacuating their contents, completely removing sloughed epidermis if the blisters are purulent, and removing foreign particles. At the end, the wound surface is covered over with an ointment dressing.

A. V. Vishnevskiy's burn-treating oil-balsam emulsion is usually used for local treatment of a burn wound (1 gm birch tar, 3 gm each of xeroform and anasthesin, 100 cm castor oil), as are synthomycin emulsion, furacillin ointment, and any other bactericidal ointment that does not have an intense irritant action, as well as preparations in aerosol containers, such as oxycort.

Boric acid is sprinkled over the ointment-bearing napkin during each dressing change in order to prevent pyocyanic infection.

Burns of the face, perineum, and external genitalia are left exposed for treatment. Injured areas are moistened with Vishnevskiy's burn emulsion or another ointment several times a day. Later, the closed method of treatment is employed as necessary.

Dressings are changed every 2-4 days depending on the general condition of the burn victim, the nature of his temperature reaction, his complaints, the stage of the wound process, and the condition of the dressing. When degree II uncomplicated burns are present the first dressing change is made 3-5 days after burning. When purulent discharge from the wound is profuse,

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dressings are changed every other day or even daily. When pyocyanic infection is present, daily dressing changes are mandatory. During the purulent period of burn wounds and rejection of necrotic tissues, it would be suitable to use dressings wetted with weak antiseptic solutions (furacillin 1:5,000, 2-3 percent boric acid solution, rivanol 1:1,000, etc.).

It is recommended that painkillers be administered to patients with extensive burns before a dressing change. Sometimes to permit painless removal of lower layers of the dressing the burn victim is placed in a tub containing a warm, weak potassium permanganate solution.

The dressings of patients with extensive deep burns (especially children) are changed while under mask anesthesia brought on with fluorothane, anazeotropic mixture, and Shayne-Ashman mixture. Totally painless change of dressings is mandatory.

When degree IIIB and IV burns are limited in area (up to 10 percent of total skin surface) and the burn victim's general condition is satisfactory, necrectomy--surgical removal of all dead tissue--could be performed early. The resulting defect is drawn closed with sutures (when the injuries are extremely limited) or covered over with a skin transplant (primary dermatoplasty). These operations would best be performed on the 5th-7th days after burning, if the boundaries of dead tissues can be determined with sufficient accuracy. Dead tissues should be excised to the point where clearly viable tissue is reached, and the depth of excision should be down to the superficial fascia as a rule.

When extensive deep burns are present early necrectomy is too traumatic and is poorly tolerated by patients. In these cases preference should be given to a more-merciful method--bloodless step-by-step necrectomy. In this method sloughing portions of dead tissues are excised gradually, in several steps, during the time of dressing changes. When there are circumferential burns on the limbs and rib cage, necrotomy (dissection of the scab) performed in the form of two or three longitudinal weakening cuts has very important significance to preventing circulatory disturbances. Necrotomy is an operation that should not be postponed.

It is recommended that the burned surface be exposed to ultraviolet radiation during dressing changes.

Primary, secondary (early and late) and repeat dermal autoplasty are performed to close a burn wound free of necrotic tissues (in the presence of deep burns). Primary dermatoplasty is defined as closing of the wound with a transplant following early necrectomy. Secondary dermatoplasty is performed in the presence of granulating wounds.

If dermatoplasty is performed 1-1.5 months after burning, it is called early secondary plastic surgery. In cases when dermatoplasty is performed later than this time, it is called late secondary plastic surgery. The condition

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of the transplant site worsens in these instances, and the percentage of unsuccessful outcomes grows correspondingly.

To close long-persisting ulcers in burn areas, they should be completely excised, and dermatoplasty should be performed (in two stages) after 5-7 days.

Repeat dermatoplasty is usually employed in step-by-step closure of wounds on victims with extensive burns.

Among all dermatoplastic methods, autoplastic transplant of a broken-up dermal panniculus 0.1-0.2 mm thick produces the best results in relation to granulating wounds, while autoplastic transplant of a panniculus 0.3-0.4 mm thick is best in restoration of skin following reconstructive surgery to correct scar deformities. Panniculi are excised with a dermatome. When the panniculus is removed correctly, spot hemorrhaging occurs over the entire area of the skin wound, and it is easily stopped by applying pressure for a short while on the bleeding area.

The areas from which the transplants were obtained become fully epithelialized in 10-12 days, and if necessary panniculi could be obtained from them once again 3-4 weeks after the first operation. The last method is resorted to only in cases of very extensive injuries, when the availability of healthy skin suitable for transplanting is limited.

Good general preparation of the burn victim and the wound itself for the transplant has extremely important significance to the success of dermal autoplasty.

When hypoproteinemia and anemia are sharply expressed, dermatoplasty may turn out to be unsuccessful: Transplanted panniculi are rejected, and previously adapted ones sometimes undergo fusion. Areas providing the transplant also undergo epithelialization poorly. In these cases, when the victim is being prepared for skin transplant he must be subjected to repeated transfusions of blood, plasma, and protein plasma substitutes, he should be given a proper diet, and vitamins and antihistamine preparations (dimedrol, suprastin, pipol'fen, and others) should be administered.

Preparation of a wound for a transplant involves removing necrotic tissues and improving the condition of granulated areas. This is achieved with repeated novocaine blockades, bloodless necrectomy, the taking of baths in weak potassium permanganate solutions, ultraviolet radiation, and application of dressings wetted with hypertonic table salt solution or antiseptic solutions. Presence of pathogenic flora on the surface of healthy granulations (naturally in the absence of clinical signs of inflammation) does not usually affect the outcome of dermatoplasty.

A burn wound can be closed with the victim's own skin (autoplasty) or skin from other people (homoplasty). Homoplasty is usually employed in relation to

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extensive burns and when the burn victim's condition is serious. After the victim's condition improves and the previously transplanted homotransplants are rejected, autoplasty is performed. Homoplastic transplants usually survive temporarily (for 2-3 weeks).

Homoplasty makes use of skin taken in sterile conditions from the corpses of people who had died accidentally (from trauma) or from stillborn children, including "waste" skin, and skin removed in surgical operations (for hernias, and so on). When skin obtained from other people is transplanted, reliable data must be present indicating that the donor was not suffering from infectious diseases (tuberculosis, syphillis, and so on) or malignant tumors. In all cases the donor must be tested with the Wassermann reaction.

Homotransplants taken from members of the patient's nuclear family do not have significant advantages over transplants obtained from other persons (except when transplanting skin from monozygotic twins).

When extensive burns are present and the possibilities for obtaining autotransplants are extremely limited, combined autohomoplasty is employed. In such cases the burned surface is covered over with alternating skin auto- and homotransplants.

Autoplasty is employed alone in the presence of burns of the face, wrists, and large joint areas.

During transplant operations the burned surface is covered over by large broken-up skin fragments or grafts of small area (the so-called postage stamp method). The postage stamp skin transplant method should not be used to cover over wounds of the face and wrists.

When panniculi wider than 7-8 cm must be transplanted as well as when wounds devoid of granulations must be closed, the grafts are usually secured to the wound margins with sutures and sewn to the edges of adjacent grafts. Thus a continuous skin cover is recreated. In this case excessive stretching of highly elastic skin grafts should be avoided, since this often causes them to die.

In order to increase the area of skin grafts they are scored with special apparatus, and when the latter is absent a common scapel is used. This should not be done (out of cosmetic considerations) when repairing defects on exposed areas of the body. When "postage stamp" or narrow panniculi are transplanted, securing sutures are not applied and the grafts are not scored.

When burn wounds are completely covered over at one time by dermal autotransplants, the wound heals relatively quickly and the functional results are better. But when extensive burns are present, closure of the entire wound with autotransplants all at one time is dangerous because this extremely traumatic operation is poorly tolerated by weakened patients. In such cases step-by-step plastic surgery is recommended.

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After plastic surgery the burn wound is covered over with napkins wetted with antiseptic solutions (rivanol 1:1,000, furacillin 1:5,000, and others), and these are covered with napkins bearing A. V. Vishnevskiy's burn-treating oil-balsam emulsion, other emulsions, or petrolatum oil.

After burn wounds on the limbs are covered over by plastic surgery, the limbs are immobilized with plaster splints for 5-6 days and, when necessary, for longer periods of time.

Principles of Step-by-Step Treatment of Casualties with Thermal Injuries

Considering that a large number of burn victims would arise simultaneously, war victims are provided aid in stages.

First aid is rendered right within the center of the disaster, first physician's aid is rendered at an OPM and in surviving therapeutic-preventive institutions near the focus of the nuclear burst and, finally, specialized aid is rendered in medical institutions of the out-of-town zone.

To prevent spread of burns, we would first have to halt all subsequent thermal exposure. For this purpose it would be better to remove burning clothing. A burning mixture can be extinguished more quickly and reliably by submerging the burning area in water or applying a special antiphosphorus bandage to the injured area and spreading antiphosphorus compound over the skin. Attempts at beating the flames help to spread the burning mixture over the body and to make it burn more intensively. First aid is aimed at fighting burn shock and preventing infectious complications. An aseptic dressing (from the individual dressing kit, or a special dressing for burn victims) is placed over the burned surface. When injuries are more or less extensive, painkilling preparations are injected with a syrette, the burned limbs are immobilized with inflatable or plastic splints, or with improvised resources when the latter are unavailable, the victims are covered with blankets, especially during the cold part of the year, they are given something hot to drink, and they are carefully removed from the disaster center.

Victims with relatively mild burns who are able to move about travel to the nearest medical evacuation stage on their own. Persons exhibiting phenomena of temporary blindness usually do not require treatment, and consequently they are not sent to medical institutions.

Aid is rendered to victims in the first stage of medical evacuation (the OPM) in strict compliance with indications established during medical sorting.

Patients with extremely severe injuries, for whom the prognosis is clearly unfavorable (deep burns covering more than 60 percent of the body), are hospitalized and treated in the given stage of medical evacuation.

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Victims with severe injuries, in a state of burn shock with burns of the respiratory tract, intense intoxication by carbon monoxide, deep circumferential burns, thermal eye injuries, and so on must be given immediate first physician's aid.

Antishock therapy given during first physician's aid consists of intravenous injection of painkillers, Vishnevskiy novocaine blockades, administration of cardiovascular perparations, analgesics, and oxygen, transfusions of antishock solutions and blood substitutes, prescription of internally administered alkaline-saline solutions, and prevention of cooling. When signs of intoxication by carbon monoxide are present it would be best to prescribe carbogen, novocaine, calcium chloride, and glucose intravenously and, if the victim is aroused and convulsing, sodium bromide. If the victim has respiratory tract burns a cervical vagosympathetic novocaine blockade must be performed, and when phenomena of asphyxia are exhibited together with pronounced oxygen insufficiency, a tracheostomy should be performed. To prevent severe complications in the presence of circumferential deep burns, necrotomy should be performed as quickly as possible, and if the eyelids and the anterior portion of the eyeball are burned, dicaine should be injected (0.1-0.25 percent solution) into the conjunctival sac, synthomycin or albucid ointment should be packed behind the eyelids, and a dressing should be applied.

An ointment dressing (Vishnevskiy's burn-treating emulsion, synthomycin emulsion, furacillin ointment, and so on) is placed over the burned surface. In addition the victim is given antibiotics, tetanus anatoxin, and serum.

If transfusion therapy is impossible, then when shock phenomena are present the victims are given hot tea or saline-alkaline solution (if vomiting is absent).

Victims with deep burns of limited area (less than 10 percent of body surface) and with chorioretinal burns are not given first physician's aid at the OPM if it is overloaded. They are prepared for evacuation to therapeutic institutions in the out-of-town zone: Depending on what the patient requires, painkillers are administered, dressings are corrected, traveling splints are applied, and so on, while in the presence of eye burns pupil dilating agents are dropped into the eyes.

Minimum aid is rendered to all casualties with limited superficial skin burns and phenomena of "nuclear" ophthalmia--dressing changes, anesthetics (0.1-0.25 percent dicaine solution), relaxants, and so on. These persons are sent to light casualty collection points, where they will receive ambulatory treatment for the most part.

After aid is rendered, all transportable casualties are sent to surgical hospitals or specialized burn hospitals in correspondence with the evacuation plan.

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Burn victims with pronounced symptoms of burn disease as well as with respiratory tract burns and burns of the eyelids, the anterior portion of the eyeball, and the ocular fundus must be sent to specialized hospitals. The rest of the victims with skin burns who do not require autoplasty or who require simple autoplasty over limited areas of the body can be evacuated to general surgical hospitals.

In the therapeutic institutions of the out-of-town zone the burn victims are given the full volume of aid and treated until recovery.

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CHAPTER 6

RADIATION BURNS

Development of nuclear weapons has created the threat of mass skin injuries resulting from contact of radioactive particles settling on man's body surface from the radioactive cloud produced by a ground nuclear burst.

Land (water) becomes radioactively contaminated not only at the focus of the burst but also along the path of the air current, causing creation of high radiation levels significant distances away from the focus. Thus, for example, the area of dangerous radioactive contamination was 180,000 km^2 following a 15 megaton thermonuclear burst on 1 March 1954 on Bikini Atoll. In this case unprotected residents of the Marshall Islands, Japanese fishermen and, in part, American servicemen were subjected to external gamma-irradiation (Table 7) and radioactive contamination of clothing and body surfaces during the time the cloud from the nuclear burst was forming its radioactive trail (Ye. Kronkayt et al., 1960; Schimitz et al., 1964).

Table 7. Relationship Between External Gamma-Radiation Dose Received and Degree of Skin Injury Experienced by Residents of the Marshall Islands (From Dunning, 1959)

Islands	Number of Persons	External Radiation Dose, r	Skin Injury		No Injury	Balding
			Deep	Superficial		
Rongelap	64	175	13	45	6	35
(Eylengine)	18	69	1	15	2	3
(Utirik)	157	14	0	0	157	0

Radiation dermatitis--radiation burns--arises as a result of contact of radioactive decay products and human skin.

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The development of radiation burns differs significantly from that of burns having other etiology. The triggering factor of radiation burns is ionization of tissues, which leads later to protein degeneration, while in regard to thermal burns, for example, protein coagulation begins right during the time of action of the thermal agent.

Burns characterized as acute, subacute, and chronic may arise depending on the dose and the irradiation time. Arisal of acute skin injuries is the most probable in the presence of radioactive fallout.

The classification of acute radiation-caused dermatitis is based on a clinical-anatomical principle according to which the severity of skin radiation injury is characterized depending on the depth and area of the burn.

We distinguish among the following clinical forms of acute radiation burns, elicited primarily by beta-particles (from B. D. Ivanovskiy, 1958; V. I. Samtsov, 1968; G. T. Chernenko et al., 1971, 1974) (Table 8).

Table 8. Degree of Skin Radiation Injury Depending on Radiation Dose

Radiation Dose, rads	Degree of Injury	Length of Course	Symptoms
400-600	Radiation reaction	2-3 days	Erythema, chills, pigmentation
600-800	Radiation alopecia	2 months	Loss of hair, desquamation, pigmentation
800-1200	Degree I acute radiation dermatitis--light injury	2 weeks	Erythema, edema, chills, a feeling of heat, loss of hair, desquamation, pigmentation
1200-2000	Degree II acute radiation dermatitis--moderate injury	4-6 weeks	Erythema, edema, pain, blisters, erosions or superficial ulcers, non-uniform pigmentation, atrophy
Over 2000	Degree III acute radiation dermatitis--severe injury	6 months and more	Erythema, edema, pain, blisters, ulcers, scars, dyschromia

Clinical pattern of injury: The radiation reaction usually manifests itself on the 1st or 2d day after irradiation; for several hours the skin looks red, and the victim experiences mild chills and a sense of anxiety; the observed dilation of vessels is functional in nature and clinically reversible. Later the place of previous erythema usually remains slightly pigmented.

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Radiation alopecia arises predominantly on the scalp. Loss of hair is temporary, and it usually begins not earlier than 1-4 weeks after irradiation. Balding develops in the 2d-3d weeks. Thus arisal of alopecia is preceeded by a rather long latent period. During balding, hair falls out in clumps in response to the slightest disturbance (combing, and even movement of the head on the pillow while sleeping).

Loss of hair is accompanied by desquamation and subsequent insignificant pigmentation. Hair resumes growth in 6-10 weeks. Hair cover recovers totally by the end of the 3d-4th months. If the skin was exposed to more than 600 rads, some of the hair follicles atrophy, and the new hair is thin, fine, and soft (B. Rayevskiy, 1959).

Degree I acute radiation dermatitis is typified by development of secondary erythema, usually on the 14th-20th days following irradiation.

The early radiation reaction of the skin is weakly pronounced and recalls the disease manifestations of lower doses (400-600 rads), described above. The latent period is 2 weeks on the average. During this time the injured area does not differ externally from intact skin. Development of erythema and edema of the skin and loss of hair are typical of the period of acute inflammatory phenomena. The victim complains of sensations of heat, chills, and heightened sensitivity and pain in the injured area. Erythema passes after 1-2 weeks, terminating with desquamation and pigmentation of the skin. Hair begins to grow back in the recovery period. Epithelial desquamation begins at the places of greatest injury, and then it spreads to the periphery. Desquamation of the skin and development of nonuniform pigmentation may go on for several months.

Injury of the skin by radioactive dust settling from a cloud produced by a thermonuclear burst and mostly containing isotopes producing low-energy beta-particles is characterized as a rule by absence of erythema. Dark brown papules or patches arise at points of contact with "hot" radioactive particles; epidermal desquamation develops subsequently at these points. During the recovery period the foci of injury appear pale with thinned epidermis, and they are surrounded by a hyperpigmented wreath. The skin becomes wrinkled (Ye. Kronkayt et al., 1960).

When the beta-particles from radioactive fallout of an atomic burst have a higher energy level, development of dermatitis is typified by arisal of widespread erythema, eliciting a sensation of burning and pains owing to pronounced edema of the skin. Erythema may acquire a violet or cyanotic hue. However, spotty hyperemia is also typical in this case, spreading to the periphery and later merging into a single focus of injury. The purplish color of erythema gradually turns yellowish. The skin's erythemic reaction is clinically reversible.

Degree II acute radiation dermatitis manifests itself with formation of blisters. The early radiation reaction, or the first phase of erythema,

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expresses itself rather distinctly and persists for 2-5 days after irradiation. The latent period is 1-2 weeks. No clinical symptoms of injury are noted during this period, and the victim feels well.

The peak period of disease begins with reddening, edema, and pains in the irradiated area. The injured skin surface rises somewhat above healthy areas. After a little while the victim begins to sense a numbing in the injured area. The increase in tension within tissues causes crushing of vessels and nerve endings. Pain intensifies sharply, causing unendurable suffering. The border between injured and healthy portions of skin is indistinct. Regional lymph nodes enlarge and become painful when palpated. Growth in edema is accompanied by formation of vesicles, which barely protrude above the skin surface at first, later merging together to gradually form large, sometimes multiple blisters. The blister fluid is amber in color, opalescent, and it dries on draining, forming a yellowish-grey crust. In the event of infection, the blister contents become turbid and purulent. Erosions sometimes form at places of popped blisters. Hair loss occurs and nails fall off during this period as well. Erythema about blisters gradually acquires a purplish-cyanotic color, and dermal edema decreases.

The dermal germinative layer joins in the process in the presence of degree II radiation dermatitis. This is why epithelialization occurs in such areas from the periphery, due to surviving cells of the basal layer. Dystrophic disturbances make healing of the injured skin area longer.

After epithelialization, small whitish scars form in individual areas, and the skin becomes marbled due to nonuniform pigmentation. The time of illness is 1-1.5 months on the average.

The process of reverse development, which is accompanied by lengthy dermal desquamation (lasting several weeks and even months), does not usually end with full recovery. Various sorts of autonomic disturbances persist in the zone of former injury--hyperesthesia, heightened sweating, vascular disturbances, and so on. The skin becomes dry, atrophic, shiny, and easily wounded, and teleangiectasias, papillomas, and areas of hyperkeratosis may form.

Degree III acute radiation dermatitis is typified by necrosis of the skin and formation of ulcers.

The early radiation reaction develops in the hours immediately following irradiation, and it persists for up to 2-3 days. The subsequent latent period is extremely short (4-6 days) or entirely absent (V. N. Petushkov, 1968).

The period of acute inflammatory phenomena begins with hyperemia, which is first bright and then turns purplish-cyan. Impairment of vascular permeability leads to edema of the injured skin and blister formation. The skin is painful and stretched. When edema develops and uninjured nerve endings

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are crushed, the pains intensify. Because of higher permeability of vascular walls, plasma protein leaves the bloodstream and coagulates. Sloughing of necrotic tissues results in ulcers with a dirty-grey or dirty-yellow floor and a purulent discharge. Regional lymphadenitis and a general temperature reaction are noted rather often during this period. The patient becomes sluggish and irritable, and he cannot sleep due to the intense pains.

The inflammatory process accompanying tissue necrosis and ulcer formation at the site of the burn develops extremely sluggishly, or it is entirely absent. Necrotic areas are indistinctly outlined, and rejection of necrotic tissues is slow. The disease is often aggravated by infection added on later. This is accompanied by growth in hyperemia, an increase in edema of surrounding tissues, and development of phlegmons. In severe cases an areactive form of sepsis develops.

The time of illness is 6 months and more. Ulcer healing proceeds extremely slowly. Retardation of connective tissue differentiation about the formed scar can be noted. Healing may not be complete, as a result of which trophic ulcers remain, which are rather often a source of complications (sepsis, amyloidosis) or malignant degeneration.

In other cases atrophic scars form at the sites of healed ulcers. After healing, the injured area is devoid of sweat and sebaceous glands, and it remains atrophic, dry, and easily wounded. Ulceration of atrophic scars at the sites of healed ulcers, formation of painful cracks, teleangiectasias, and skin growths (warts, papillomas, areas of hyperkeratosis) are typical of this stage of disease.

Prevention and treatment: The clinical pattern of radiation dermatitis, as described here, manifests itself at different levels of skin contamination by the radioactive products of a nuclear burst. Their half-life has important significance in this case. Basing ourselves on the absorbed radiation doses given in Table 2 and using the graphs plotted by Dunning (1959), we can determine the dynamics behind change in injurious and noninjurious levels of skin contamination by radionuclides depending on the time from the moment of the nuclear burst to the moment they settle on the body surface (Figure 7).

The curve of the noninjurious or permissible, for wartime conditions, level of skin contamination by radioactive fallout increases from 1.4 $\mu Ci/cm^2$ when the period of decay is 24 hours to 6.5 $\mu Ci/cm^2$ when fallout settles 1 hour after the burst. It is usually found to be rather difficult to determine the age of radioactive fallout, especially when several nuclear bursts occur. This is why the permissible density of skin contamination is set in many countries within 1-2 $\mu Ci/cm^2$.

All persons finding themselves in the path of the radioactive trail must enter radiation shelters or other improvised shelters. In the event radioactive contamination occurs, steps must be taken at the first opportunity

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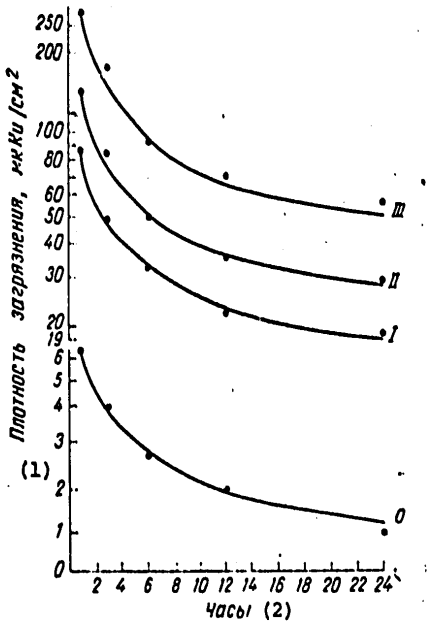

Figure 7. Mean Expected Permissible (*0*), for Wartime Conditions, and Injurious (Degree *I*, *II*, and *III*) Densities of Skin Contamination by Radioactive Products of a Nuclear Burst Depending on Their "Age."

Key:

1. Contamination density, $\mu Ci/cm^2$
2. Hours

to remove fallout from skin and clothing, so that accumulation of injurious radiation doses could be precluded. The indication for cleansing of the body is an individual's presence on open terrain, for even a short time, during formation of the radioactive trail.

Casualties travel from contaminated areas to the receiving and sorting department of the OPM, after first undergoing personal cleansing. If the OPM is located on territory that is not contaminated by radioactive substances, casualties can be subjected to dosimetric control.

When contamination of clothing and skin by radioactive substances is detected, the casualties are subjected to partial or complete personal cleansing at the personal cleansing point. Partial personal cleansing includes washing of exposed portions of the body (face, neck, hands) with soap and water.

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Complete personal cleansing includes:

Removal of clothing and its decontamination;

a long warm shower with soap and washcloth;

repeat dosimetric control for residual contamination.

This cleansing method removes up to 80-100 percent of the radioactive particles from the body surface. Personal cleansing is effective when it is performed 6-10 hours after radioactive substances settle on the skin.

In the event acute signs of radiation dermatitis arise, treatment is prescribed depending on severity of injury.

In the presence of mild radiation dermatitis the injured areas of skin are smeared with lanolin and covered with a dressing saturated with fish fat or sea buckthorn oil. This reduces the burning sensation and relieves pain.

In addition to prescription of antiinflammatory agents (ice packs, lotions, mixes, ointments), degree II radiation dermatitis requires prescription of intravenous administration of rheopolyglucin, dextran (400 ml) or hemodes (200-300 ml).

In the event the blister exudate becomes purulent, dissection and removal of sloughed epidermis is recommended. A dressing covered with antiseptic ointments is placed on the resulting wound surface. The injured area can be anesthetized with novocaine administered as a blockade, by electrophoresis, and intraarterially (A. A. Gabelov, L. P. Larionova, 1968). Reduction of the permeability of dermal vessels is promoted by intravenous dropwise infusion of trasylol at a dose of 50,000-100,000 AU daily. In addition we prescribe antibiotics and antiinflammatory substances (antihistamines, corticosteriod preparations) as well as antiseptics to prevent suppuration in injured areas of the skin: Dressings saturated with furacillin solution (1:5,000) or rivanol (1:1,000), or gauze dressings bearing streptocidal emulsions. Analgesics, soporifics and, if the indications require, narcotics bring doubtless relief to the casualty.

It is important to raise the body's protective forces and normalize regenerative processes at the peak of illness. For these purposes we prescribe an intensified diet rich in proteins and vitamins, transfusion of small quantities of blood (up to 200 ml), autohemotherapy, administration of aloe leaf extract, and so on.

In the presence of ulcerous-necrotic radiation dermatitis conservative therapy usually produces only temporary improvement, failing to support stable healing. Surgery is recommended in such cases. Usually the radiation ulcer is excised as far as healthy tissues, and the wound is sutured.

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If the wound cannot be sutured, an autodermal panniculus must be transplanted (B. A. Zadorozhnyy, M. V. Zvyagnitseva, 1966).

Physiotherapeutic procedures, massage, and therapeutic physical culture are prescribed in the recovery period.

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PART TWO

PARTICULAR PROBLEMS OF MILITARY TRAUMATOLOGY

CHAPTER 1

INJURIES OF THE HEAD AND NECK

Neurosurgical Aid to Casualties With Cerebrocranial Trauma

The lives of neurosurgical casualties depend on prompt first aid and conduct of a complex of therapeutic measures based on vital indications at the OPM. The plans call for rendering the full volume of specialized neurosurgical aid in institutions of the hospital base, where hospitals specialized for the treatment of head, neck, and spinal wounds will be deployed and all of the conditions for diagnosis and treatment of neurosurgical casualties will be created.

Closed cranial injuries are subdivided into two basic groups:

1) Without injury to bones--brain concussion, contusion, or growing compression of the brain coupled with development of subarachnoid hemorrhaging, formation of intracranial hematomas (epidural, subdural, intracerebral, intraventricular), and development of traumatic edema--brain swelling;

2) with injury to bones, including multiple hairline fractures of the cranium spreading from the area of the fornix to the base of the skull and accompanied by contusion of the brain's basal divisions, the brain stem (along the course of the fractures) or the convex surface of the brain, both at the place of a compressive or splintered fracture and in a remote area, in the zone of the countershock.

Open injuries to the skull and brain can arise through the action of secondary (nongunshot) missiles and in the presence of gunshot wounds. In the presence of nongunshot wounds we usually observe lacerations and contusions of various dimensions and shape, with damage only to soft tissues or with injury to bone, the cerebral membranes, and the brain. Incised, puncture, and scalp wounds are encountered significantly more rarely.

Gunshot wounds of the cranium and brain can vary in nature: Fragment and bullet (spherical, arrow-shaped, and other wounding missiles), blind,

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tangential, through, and ricochet. In terms of location these may be wounds of the fornix or base of the skull (parabasal), they may occur on the right or on the left, they may be single, multiple, and combined, they may occur with injury to other organs and systems, and so on.

Specific Features of Rendering First Aid

First aid in the presence of closed injuries to the skull and brain mainly involve freeing the respiratory passages and keeping vomit out of them. A quick examination must be made of the casualties, especially those that are unconscious, in order to determine the state of vitally important functions, and to not miss accompanying fractures of the ribs, limbs, and spine. This has significance to the choice of first aid resources and to the method by which the casualty is removed from the disaster center.

First aid in the presence of open injuries to the cranium involves application of an aseptic dressing to the wound. If vomiting or nosebleed arises the casualty should be laid on his side.

In the event that aid is being rendered by a medical worker with the proper equipment available, administration of cardiac agents and painkillers (when injury to the skull is combined with injuries to other organs or with burns) is indicated.

Specific Features of Sorting at an OPM

Beginning as early as in the first stage (at the OPM), special attention should be turned to neurosurgical casualties.

Loss of consciousness (on arriving or in the recent past), signs of trauma, bruises on the head or hemorrhaging, bleeding from the nose or ears, dilation of the pupils, vomiting, headache, disturbances in vision, hearing, and speech, various forms of paralysis and paresis, weak pulse, and other signs imply closed injury to the skull and brain.

Outflow of liquor for broken-down particles of brain matter (detritus) from head wounds would indicate extremely severe injury of brain matter in the presence of open skull wounds.

Ambulatory casualties make up the largest group at an OPM. This group is heterogeneous, and it requires persistent attention, since it may contain many neurosurgical casualties. Ambulatory casualties would consist mainly of persons with extremely light injury and insignificant brain injuries--bruises on the scalp, surface wounds in soft tissues of the skull that do not penetrate deeper than the aponeurosis, and brain concussion having insignificant clinical manifestations (mild concussion). As a rule such casualties do not require lengthy treatment. In 3-5 days the lightest casualties of this group could be formed into teams or groups to provide services to severe

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casualties, to keep the rooms clean and in order, to feed casualties, to move them to the dressing ward, and so on.

At the same time the large group of ambulatory patients could also contain casualties with injury to soft tissues of the skull, earlier brain concussions, and contusions of the spine without gross damage to the spinal cord. After their examination and after a preliminary diagnosis confirms or offers grounds for suspicion of injury to the central nervous system, the casualties must be sent to specialized therapeutic institutions of the hospital base.

The ambulatory group could include casualties whose state noticeably worsens while in the OPM. They require especially persistent attention. A worsening of condition occurring among some casualties while awaiting transportation may be the result of developing traumatic brain edema, weakness of cardiovascular activity, development of shock, an initial reaction to radiation injury, and other causes. Such casualties must be examined by a physician, who should establish the cause of the deterioration in state. Then he must prescribe treatment in accordance with the established pathology--administration of dehydrating or antishock agents, analeptics, and so on. An especially dangerous cause of worsening in a patient's state may be unchecked intracranial bleeding resulting in cerebral compression. Such casualties require immediate surgery based on vital indications.

Stretcher cases require a differentiated approach depending on the nature of injury--closed or open trauma of the skull and brain, and combined injuries.

The following should be distinguished among all of these types of injuries:
a) Persons who are conscious and do not exhibit signs of pronounced shock. They are subject to planned evacuation to the hospital base by all forms of transportation, including in rail transportation adapted for conveyance of stretcher patients;

b) casualties with skull and brain injuries who are unconscious but do not exhibit signs of disturbances in vitally important functions (respiration, cardiovascular activity, swallowing). After examination by a physician, dressing of wounds, and exclusion of factors which might be a threat to the life of these casualties (cerebral compression, ventricular liquorrhea, severe shock, and so on), they should be evacuated on priority to specialized therapeutic institutions, after first being given drugs improving cardiovascular activity and raising the body's overall tone. Medical personnel must keep casualties in this group under observation while en route;

c) casualties in a state of pronounced shock, coma, with disturbances in breathing or cardiovascular activity, with pronounced liquorrhea, with frequently recurring epileptic seizures, and in a state of psychomotor arousal. Therapeutic measures must be implemented in relation to this category of casualties as required by the vital indications--antishock therapy or

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emergency surgery. Some such very severe patients may be categorized as hopeless cases, and they would require rest and a conservative medical approach. After examination by a physician secondary medical personnel should continue treatment of such incurable casualties so as not to distract physicians from providing aid to those who could be saved (with increasing intracerebral hematomas, ventricular liquorrhea, shock, acute brain edema, and so on).

Neurosurgical Intervention Based on Emergency Indications

Closed Injuries

When closed injuries of the skull and brain are present, victims with growing intracranial pressure (brain compression) must be revealed. These casualties must be subjected to surgery on the basis of vital indications. Before this, steps are first taken to determine the nature of compression and to locate the place of intracranial hemorrhaging (administration of dehydrating drugs, performance of a lumbar puncture, and measurement of liquor pressure). When the clinical pattern is unclear we use the novocaine test (25-30 ml 1 percent solution is slowly infused intravenously), which noticeably deepens neurological prolapse: Hemiparesis increases, paresis of the oculomotor nerve (dilation of the pupil) intensifies, and so on. This permits us to reveal a latent pathological focus (in this case a hematoma) in doubtful cases and establish the indications for immediate surgery. Very serious complications are often encountered in determining the location of a hematoma. In such cases examination of the head and determination of neurological data (dilation of the pupil on the side of hemorrhaging, hemiparesis and absence of abdominal reflexes on the opposite side, speech disturbances) facilitate topical diagnosis. Sometimes when searching for a hematoma it is necessary to drill several holes on the suspected side of hemorrhaging.

Surgery following discovery of a hematoma boils down to enlarging the drilled hole, removing blood clots, and stopping the bleeding, if it had not stopped on its own by this time.

When acute traumatic brain edema is present we observe a pattern similar to that of the intracranial bleeding symptom complex. But the hypertension syndrome progresses more mildly in such cases, gross focal symptoms do not grow in expressiveness and, what is very important, a distinct therapeutic impact is achieved with dehydration therapy.

It may turn out to be impossible to take all steps to clarify the nature of brain compression due to drastic disturbances in the victim's breathing. This is often the cause of his death, since breathing disturbances of central origin lead quickly to pulmonary edema, accumulation of mucus in the respiratory tract, impairment of its expectoration owing to lower sensitivity of the larynx and spasms of the glottis, and as a consequence to a dramatic increase in brain oxygen starvation. Tracheostomy, aspiration of mucus from the bronchi, and artificial ventilation of the lungs would be

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vitally indicated in such cases. The group of casualties with closed brain injuries requiring surgery based on vital indications will represent about 1-1.5 percent of all casualties.

Another group consists of casualties with closed fractures of the fornix and base of the skull with nasal and aural liquorrhea, and with phenomena of subarachnoid hemorrhaging coupled with pronounced focal disturbances of nervous activity. These casualties (making up about 10 percent of persons with closed skull and brain trauma) must be sent to a specialized neurosurgical hospital.

Open Injuries

Injuries of the skull and brain are subjected to surgery in an OPM only on the basis of vital indications. First among them is hemorrhaging (external or intracranial). Typical signs of unchecked intracranial bleeding are: Progressive worsening of state, intense headaches, initial psychomotor arousal which soon transforms into a depressed state, bradycardia, labored pulse, vomiting, growth in intensity of general cerebral symptoms, and dilation of the pupil on the side of the hematoma.

The surgical principles followed in the presence of an intracranial hematoma boil down to resection of wounds in soft covering membranes, trepanation of the traumatic bone defect, and removal of the hematoma (epidural, subdural, or intracerebral, usually located along the course of the wound channel) and arrest of bleeding. With this goal, the membrane vessels are carefully sutured, and ligatures or clips are applied. A 3 percent solution of hydrogen peroxide, a hemostatic sponge, and warm physiological solution have a good effect against parenchymatous hemorrhaging.

Emergency cranial surgery is performed on the basis of vital indications also in the presence of profuse drainage of cerebrospinal fluid from the wound, which happens in cases of wounding of a brain ventricle. Wetting of the dressing and of the head support and rapid dehydration of the body attest to liquorrhea. If immediate steps are not taken to halt liquorrhea the brain ventricles may collapse--that is, liquor production will cease, leading to death. In addition it should be considered that a gaping wound channel through which liquor flows out of a ventricle is an open gate through which microbial contamination of the wound spreads to the deeper divisions of the brain, which can lead to development of serious complications such as encephalitis, ependymitis, and basal meningitis.

The surgical principles followed with liquorrhea boil down to economical resection of the wound margins, trepanation of the traumatic defect in the skull, removal of bone fragments from the wound channel (cerebral detritus and hematomas are usually flushed out by draining liquor), and mandatory application of a tight suture in soft covering membranes to halt liquorrhea. Following surgery, casualties with penetrating wounds of the skull require preventive (or therapeutic) administration of antibiotics. They are

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nonstransportable for not less than 3 weeks, which is a hard thing to do in this stage of medical evacuation. In quantitative respects the group of casualties requiring emergency surgery on the basis of vital indications represents 1.5-2.5 percent of all cranial and cerebral casualties.

Among victims with open injuries to the skull and brain, 1-1.5 percent are casualties in a preagonal or agonal condition. Implementation of reanimation measures is indicated for such casualties, and if they are unsuccessful, symptomatic therapy can be employed.

All other cranial casualties who have received an intramuscular antibiotic injection and, if the indications are present, hypertonic glucose solutions, cardiac or respiratory analeptics, and neuroplegics or anticonvulsive drugs (and radioprotective drugs in the presence of special indications) are subject to evacuation to a neurosurgical hospital. Such patients should undergo evacuation lying down, and desirably in comfortable transportation. A casualty's unconscious or somnolent state is not a contraindication to evacuation when respiration and cardiac activity are good. Immobilization for transportation is not mandatory in these cases, with the exception of cases of cranial-spinal wounds or their combination with possible injuries to the principal vessels to the neck.

When evacuating casualties with cranial and cerebral trauma it should be remembered that they suffer more from a bumpy ride on rough dirt roads than when evacuated by air or rail. Helicopter evacuation has its advantages in this respect. The slight vibration experienced by contused and wounded patients flying in a helicopter does not elicit painful manifestations.

While there are no objections to evacuating cranial casualties by air, casualties with closed skull and brain traumas have a poor tolerance of such evacuation; this is true, for example, of patients with contusions of the basal divisions of the brain or with severe fractures of the base of the skull. Such casualties must be provided rest in the first stage (the OPM) for a minimum of 5-7 days, during which time they are subjected to dehydration therapy and therapy stimulating respiratory and cardiac activity.

Specialized Aid

Specialized neurosurgical aid is provided by neurosurgical hospitals possessing all of the necessary specialists (a neurosurgeon, a neuropathologist, a stomatologist, an ophthalmologist, and an otorhinolaryngologist) as well as the required equipment and special surgical instruments. The task of the neurosurgical hospital is to render complete specialized aid. In addition to receiving and sorting and medical departments (one for each specific type of wound), the hospital should have a diagnostic department in which diagnostic problems are resolved and indications for initial wound processing are determined in relation to the most complex injuries.

An examination is made to establish the diagnosis of the injury, and neurosurgical casualties are then sorted into the following five groups:

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With penetrating wounds of the skull and brain;

with nonpuntrating wounds of the skull (when there is damage to bone but the integrity of the dura mater persists);

with wounds of soft tissues of the head;

with closed cranial fractures or the compression syndrome;

with open and closed injuries of the spine and spinal cord.

Depending on the states of the casualties, the time following injury, and presence or absence of combined injuries, each of these groups of casualties undergoes initial processing in the surgical ward and receives the full volume of specialized aid (when cranial and cerebral injuries are present), undergoes processing in the dressing ward (when soft tissues are wounded), or receives conservative therapy after the casualties are brought to an operable state.

Neurosurgical measures are implemented against intracranial and spinal nonsuppurative and suppurative complications (prolapses--protrusion of the brain, liquor fistulas, meningitis, meningoencephalitis, cerebral abscesses, cerebral gas gangrene, epiduritis, osteomyelitis, epilepsy, arachnoiditis, and so on) in the stage of specialized aid.

Significant manpower and resources are required for the prevention and treatment of nonsuppurative and suppurative complications accompanying cerebrocranial and craniospinal injuries.

We should add to this that the tasks associated with restorative therapy for neurosurgical casualties will also be completed at this stage.

Injuries to the Face and Jaws

Gunshot injuries to the face and jaws, according to data from the Great Patriotic War, made up 3.5 percent of the total casualties.

Gunshot injuries of the face and jaws were distributed as follows: Isolated injury of soft tissues of the face (40.2 percent), wounding of the lower jaw (28.5 percent), wounding of the upper jaw (14.3 percent), wounding of both jaws (6.8 percent), wounding of the cheekbone (4.1 percent), injury to upper teeth and bones of the lower jaw (3.4 percent), injury of lower teeth and bones of the upper jaw (1.4 percent), and injury to teeth of both jaws (1.3 percent). Injury of the hyoid bone was noted in sporadic cases.

Thus 60 percent of the wounds of the jaws and face involved bone injury, and consequently these casualties were categorized as seriously wounded. The severity of injury was aggravated by the fact that 32.5 percent of the

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casualties simultaneously had multiple and combined injuries. Facial wounds were accompanied by wounds in the following regions: The neck--17.3 percent, upper limbs--8.6 percent, chest--3.3 percent. In addition 13.6 percent of the casualties with wounds of the face and jaws simultaneously had injuries of the eyelids and eyes (4.6 percent), the nose (3.7 percent), the skull (3.4 percent), and the ear (1.9 percent).

Injuries of the face and jaws are possible in a modern war owing to the action of so-called secondary missiles, as is severe trauma resulting from the crushing of individuals by falling parts of destroyed buildings, landslides, and other causes.

The specific features and severity of face and jaw injuries require the services of a physician with high qualifications and a broad range of surgical skills permitting him to diagnose and evaluate the condition of the casualty and devise the treatment plan with a consideration for prevention of complications.

When examining a casualty who had received injuries of the face and jaws in a combat situation, the physician must orient himself on the basis of a particular working classification of combat pathology: Injuries are distinguished in relation to the type of weapon, and the nature of wounds and injuries is described.

It is almost impossible to describe all variants of injuries in modern combat pathology, which is distinguished by high incidence of injury and extreme diversity. It would be sufficient to know that wounds can occur on any area of the face, and there is no variant of damage to soft tissues and bones, beginning from the most inconsequential and ending with extensive destruction and damage of the face, that a surgeon would not encounter while treating injuries of the jaws and face. Consequently, knowing the fundamental principles of surgical processing and treatment of wounded and injured individuals, the methods for treating combined traumas, the means and variants for immobilizing fractured jaws and facial bones, the methods of controlling and preventing complications, and the techniques of caring for and feeding casualties, the physician will always be able to provide the needed individual medical aid in all conditions and to every victim.

First Medical Aid

A number of unique features must be considered when rendering first medical aid to casualties with injuries of the jaws and face: The impossibility of using conventional personal gas masks, the inconsistency between the appearance of the injuries and the severity of trauma, profuse hemorrhaging, the perpetual threat of asphyxia, the undesirability of applying dressings causing pressure, disturbance of swallowing in victims, and the impossibility of eating. It is important to consider all of this when providing first aid.

The tasks of first medical aid include preventing asphyxia, both dislocational (caused by movement of the tongue and jaw fragments) and aspirational (caused

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by aspiration of blood, mucus,, and vomit). For this purpose the casualty is laid face down or on his side with the head turned in the direction of the wound (Figure 8).

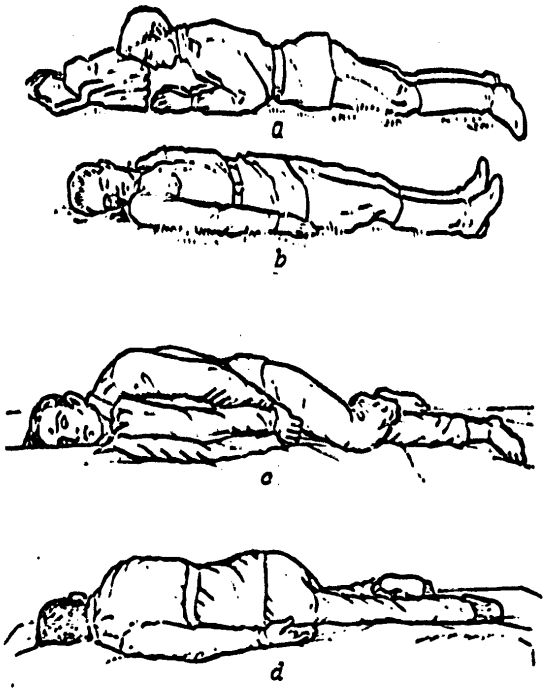

Figure 8. Positions of Casualties Threatened by Dislocational and Aspirational Asphyxia: *a*--Lying face down; *b*--lying on the back (the head is turned in the direction of the wound); *c*--lying on the side (front view); *d*--lying on the side (back view)

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If first aid is being rendered by experienced secondary medical personnel or a physician, then if asphyxia is caused by swallowing the tongue the latter could be sutured down or pierced with a safety pin and arrested. When breathing stops, artificial respiration is usually performed in combination with indirect heart massage. It should be considered that when wounds are present on the face and in the mouth cavity and nose, it is often impossible to perform mouth-to-mouth or mouth-to-nose artificial respiration.

A sterile dressing should be applied to a facial wound; in this case loose shreds of soft facial tissues must be carefully laid in place. This promotes maintenance of the position of tissues, quick arrest of hemorrhaging, and reduction of tissue edema.

Casualties with facial and jaw wounds must be sought for actively, since owing to injury and wounds of the face, jaws, and tongue, speech is impaired and the victims cannot call out for help. Moreover 20 percent of such casualties are observed to have concussions and contusions of the brain coupled with loss of consciousness.

Bleeding from small branches of the superficial and profound facial arteries usually stops on its own a few minutes after infliction of the wound. If bleeding has not stopped, a simple or pressure bandage should be applied, but in this case it should be considered that application of a pressure bandage is dangerous when fractures of the jaws and facial bones are present, since this can cause displacement of bone fragments and the undesirable consequences of that.

If first aid is rendered in more-favorable conditions and by a physician, then of course the more-radical means for arresting bleeding are possible. It all depends on the general situation and on who is giving first aid and where.

When evacuating casualties, systematic control should be maintained over dressings, and they should be straightened or tightened as required. In winter, if a dressing has become saturated with blood and saliva, it should be replaced to avoid freezing of the face. When a wet dressing freezes, it makes breathing difficult for the casualty.

When signs of dislocational asphyxia are present the tongue should be secured in optimum position. With this goal it is sutured with No 6-8 silk thread along the midline for 2 cm, after which the tongue is drawn forward, to the teeth. The thread is tied to the upper teeth or to a rigid chin strap, or it is tied to a bandage wound above the neck. The tongue can be arrested quickly and well with a safety pin from the personal first aid kit; in this case the tongue is pierced by the pin from top down or from left to right, after which a thread is tied to the pin and secured as indicated above. Allowing the casualty to drink his fill is mandatory, especially in summer, since blood loss and profuse salivation can cause dehydration of the body.

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Due to the danger of asphyxia, morphine or pantopon can be administered only simultaneously with lobeline and cytiton when implementing antishock measures or during evacuation. Casualties should be evacuated without delay. Most of them (assuming brain concussion and radiation had not occurred) can travel on foot, some can be transported sitting down, and only about 15-20 percent would require evacuation on stretchers.

First Physician's Aid

First physician's aid in response to injuries of the face and jaws must be oriented at implementing measures as required by vital indications (control of shock, bleeding, and asphyxia).

Hemorrhaging is stopped by applying a ligature to the vessel in the wound, tamponing it, suturing tampons into the wound, tamponing the wound and subsequently suturing the skin (this must be noted down on the card or in the disease history!), and applying a ligature to a length of the vessel. When bleeding occurs from the oral cavity, the latter must be meticulously inspected, blood clots and foreign bodies must be removed, ligatures must be applied to bleeding vessels, wounds on mucous membranes and the tongue must be sutured, and the cavity at the location of the bone (skull) defect must be tightly packed with tampons.

Nosebleed is stopped by applying sutures to the wound, straightening fragments of the nasal bones, and inserting narrow, long gauze tampons into the external nares. When bleeding occurs from the posterior divisions of the nose, Belloc's anteroposterior method of applying tampons is used. Bleeding from the nose can be stopped by inserting rubber or polychlorvinyl tubes with a diameter of 7-8 mm and a length of 12 cm (as far as the choanae) into the lower nasal passages, securing their ends to the face with a thread, a bandage, or a patch.

If bleeding from the mouth cavity, the nose, and the nasopharynx cannot be stopped by the method indicated above and if it is impossible to determine the side on which the vessel--the external carotid artery in particular--should be ligated, tracheotomy followed by firm packing of the pharynx and the wounds in the mouth cavity is indicated (!) with the goal of preventing blood loss and aspirational asphyxia. In this case a careful individual approach must be taken to the care and feeding of the casualty through a probe inserted into the nose. After 48 hours the probe could be removed, and if the casualty's state is not critical, he could be evacuated.

Prevention of Asphyxia

The asphyxia classification in use today (Table 9) permits the physician to choose the correct tactics in the treatment of this menacing complication, which is encountered in 5 percent of all cases of face and jaw trauma.

When dislocational asphyxia occurs, the tongue is sutured and secured, and displaced jaw fragments are returned to place; a tracheotomy is required in

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rare cases; obturational asphyxia requires removal of all foreign bodies hindering free breathing.

Stenotic asphyxia would require dissection of wounds in the submaxillary triangles and on the neck with the goal of reducing pressure on the tissues, removal of hematomas and foreign bodies, and tracheotomy.

Table 9. Classification of Asphyxia, and Its Frequency of Occurrence in the Presence of Facial and Jaw Traumas

Form of Asphyxia	Pathogenesis	Frequency, Percent
Dislocational	Displacement of the tongue, and of jaw and larynx fragments	40
Obturational	Closure of upper respiratory passages by blood clots and foreign bodies	29
Stenotic	Crushing of tracheae (edema, hematoma, emphysema)	23
Valvular	Closure of the entrance to pharynx by shreds of soft tissues (usually of the soft palate)	5
Aspirational	Aspiration of blood, vomit, etc.	3

When valvular asphyxia is present, shreds of soft tissues should be sutured in place.

Aspirational asphyxia requires prompt stoppage of bleeding from wounds in the oral cavity, pharynx, and nasopharynx. If this cannot be done, a tracheotomy is performed, followed by packing of the pharynx and mouth cavity with tampons.

When fracture of the jaws occurs, the jaws must be immobilized with a standard chin splint. This splint consists of a cloth cap, a rigid chin sling, and rubber rings with which the sling is secured to the head bandage (Figure 9). To avoid formation of sores beside the internal surface of the sling, before the bandage is put on a cotton gauze pad 3-4 cm thick is applied.

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Figure 9. Temporarily Securing Jaw Fragments by Applying a Stock (Standard) Traveling Bandage

Sometimes in order to secure large jaw fragments teeth on opposite jaws are tied together by aluminum brass wire 0.5 mm in diameter. But when comminuted fractures occur, such fixation can lead to displacement of jaw fragments, and for this reason such binding of the teeth must be avoided. Binding of teeth on opposite jaws as well as pressure sling bandages are contra-indicated when there are signs of encumbered breathing and vomiting (!).

When rendering first physician's aid, the physician must not dissect facial wounds with the goal of removing foreign bodies. When facial burns are present bandages that cover the entire face as a mask should not be applied, since replacement of such a bandage at the next stage of evacuation is a painful, lengthy operation. It would be better to cover facial burns with a dressing made out of individual gauze balls saturated with the appropriate medicinal agents, which are applied like "tiles" to the entire injured area. Such dressings are easily replaced at the time of their changing.

Facial and jaw traumas combined with radiation injury require meticulous care of the mouth cavity, teeth, and dentures. When radiation injuries occur in the mouth cavity in combination with ulcers, necroses of soft tissue, and other complications, special therapy to reduce salivation is performed simultaneously with caring for the mouth cavity.

Specialized Aid

Casualties undergo meticulous comprehensive examinations, including roentgenological, laboratory, and so on, in specialized therapeutic institutions

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under the observation of highly qualified physicians, mainly surgeons-stomatologists. Roentgenological examination is employed to determine the nature of damage to facial and cranial bones, and to locate foreign bodies. Specialists are called in for consultation as necessary for examination and treatment, to include oculists, otorhinolaryngologists, neurosurgeons, therapists, and so on. It is in the specialized therapeutic institutions that radical surgery is performed on wounds to remove foreign bodies, reposition bone fragments, and secure them with various splints and apparatus, including laboratory-manufactured ones. Complications--aspirational pneumonia, osteomyelitis, phlegmon, abscesses, sepsis, and so on--are treated concurrently. Organization of the prevention and treatment of later secondary hemorrhaging occupies a special place.

When combined injuries occur, casualties are subjected to general processing and wounds are surgically treated.

Specific Features of Caring For, Feeding, and Transporting Victims With Facial and Jaw Traumas

A favorable outcome in the treatment of all forms of facial and jaw injuries depends in many ways on the way care for, feeding, and transportation of this category of victims are organized.

General care can in principle be the same as in relation to all casualties, though the specific features of damage to the face and jaws must be considered. First of all the physician must know how to communicate with the victim--with words, or in writing. Understanding can be reached only with the alphabet (using letters and numbers) with victims with injuries of the face and hands and able to neither speak nor write.

In order that the dressing would not become wet, a transparent polyethylene or polychlorvinyl bag is placed over the head, covering the entire head and neck for the time of personal cleansing.

If it is not contraindicated, a victim in a cot or on a stretcher should be placed in reclining position, which facilitates breathing and prevents aspiration of saliva, mucus, blood, and pus into the respiratory tract.

To prevent congestive phenomena in the lungs and development of aspirational pneumonia, the casualties should be turned from one side to the other more frequently. Round suction cups, sulfanilamide preparations, and antibiotics are prescribed.

Salivation can be decreased by administering aeron tablets or 6-8 drops of belladonna extract, or 1 ml 0.1 percent atropine solution is injected subcutaneously. Atropine must also be injected prior to the victim's evacuation. The patient's clothing and chest and his pillow are kept from becoming wet with saliva by polyethylene film or a medical apron; in some cases saliva receptacles made from a rubber heating pad or a polyethylene bag (Figure 10) are suspended from the chin.

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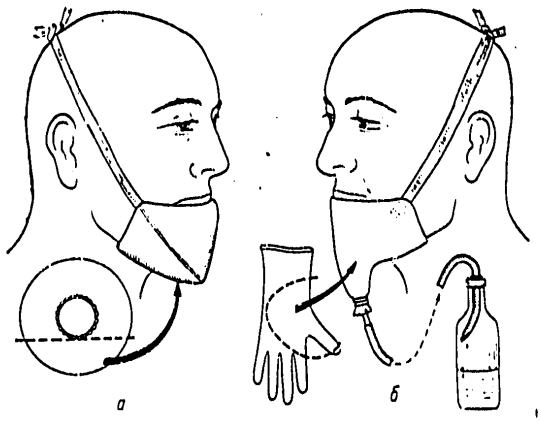

Figure 10. Saliva Receptacles: *a*--Made from a rubber heating pad; *b*--made from a rubber glove or polyethylene bag

After cleaning the face during replacement of dressings, facial skin must be lubricated with white zinc ointment, boric alcohol, or 10 percent aqueous copper sulfate solution to prevent maceration of the skin.

Oral hygiene is performed regularly, five to six times a day, involving rinsing of the oral cavity, the spaces between teeth, splints, and dentures. Rinsing is done with a 1:5000 nitrofurazone solution, a 1:5000 aqueous potassium permanganate solution, or a weak aqueous sodium bicarbonate solution.

If breathing through the mouth dries out the casualty's mucous membrane, it would be suitable to lubricate the palate, tongue, and the entire mucous membrane with butter, glycerine, or any neutral fat.

Feeding persons with facial and jaw wounds is an extremely critical and sometimes difficult task. The victim can be fed with a teaspoon, from the tip of a drinking bowl with an elastic tube (Figure 11), from a funnel outfitted with a tube, from a polyethylene bag and, finally, with a probe inserted into the esophagus through the lower nasal passage.

It would be best to feed the casualty through a polychlorvinyl elastic transparent tube with a diameter of 0.8-1 cm; movement of the food can be easily seen in such a tube.

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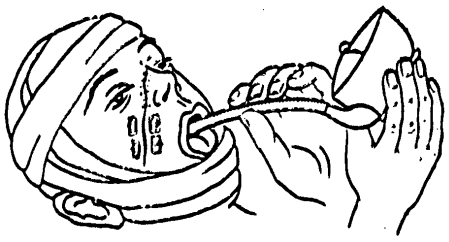

Figure 11. Feeding a Casualty from a Watering Bowl with an Elastic Tube

A liquid diet (with a pasty consistency) can be prepared out of special concentrates or out of ordinary food which is first passed through a meat grinder and then through a sieve. Pulverized dry black bread and mashed peas must be added to the food. The prepared food should pass easily through the tube. Some medicines can be administered together with the food.

The casualty must receive from 2,500 to 4,000 kcal per day. It would be desirable to give four to five meals per day. After the casualty finishes eating, remaining food should be removed from the mouth with forceps, after which the mouth is carefully rinsed.

When evacuating victims with facial and jaw wounds in motor transportation, we must consider the condition of the roads, the distance, and the condition of the casualty. When long distances are involved it would be better to evacuate casualties in lying position, placing their heads in the direction of travel. When casualties are conveyed by airplane, helicopter, or water, precautionary measures must be taken, especially in relation to persons suffering air- and seasickness in connection with the possibility of vomiting, intermaxillary arresting devices should be removed, and tension of rubber bands on chin slings should be weakened.

To avoid facial frostbite in winter, dressings wetted with aqueous solutions should not be applied. All dressings must be applied over fat emulsion or fish fat.

Injuries to the Ear, Throat, and Nose

During the Great Patriotic War ear, nose, and throat injuries made up about 4 percent of all injuries, while contusive injuries with damage to hearing organs, the throat, and nose dominating made up 2 percent.

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Use of modern nuclear weapons means the possibility of sharp fluctuations in pressure (barotrauma) in combination with the action of a sound wave (accoustic trauma), which leads to damage of the eardrum and the middle and inner ear. Phenomena of general contusion will often be present.

Light injuries: Rupture of the eardrum and vessels in the submucosa of the nasal cavity, and wounding of soft tissues of the nose, ears, and neck.

Moderate injuries: Wounding of the nose, simple fractures of nasal bones, and wounding of the ear coupled with bone damage.

Serious injuries: Wounding of the walls of the nasal cavity, wounding of the antra of Highmore and the ethmoid labyrinth, wounding of nasal cavities, wounding of the pharynx, and open and closed wounds of the larynx, trachea, and esophagus.

First aid involves applying dressings to wounded surfaces, providing for free breathing, preventing asphyxia, and temporarily stopping bleeding.

First physician's aid to ear wounds coupled with bone damage threatened by arterial bleeding involves ligation of the internal or even the common carotid artery on the appropriate side for the length of the wound.

Bleeding accompanying wounds of the nose and nasal cavity is stopped by applying a pressure sling-type bandage and by firm packing of the anterior nasal passages with long gauze tampons, coupled with the use of hemostatic resources. If bleeding cannot be stopped in this way and blood continues to drain through the mouth, posterior packing with tampons is additionally performed, before anterior packing. When bleeding is persistent, ligation of the external or internal maxillary arteries is permitted.

In cases of deep wounding of the nose and sinuses (combined wounding of the nose and sinuses; wounding of the nose and sinuses combined with injuries to contiguous areas; wounding of the nose and sinuses penetrating into the cranial cavity), first physician's aid additionally includes arrest of bleeding through anterior and posterior packing with tampons and application of a pressure bandage coupled with the use of hemostatic resources. When bleeding from branches of the internal maxillary artery is persistent, we sometimes resort to ligation of the external carotid artery.

When the chewing apparatus is severely damaged the patient must be fed through a stomach probe.

When the pharynx, larynx, trachea, and cervical portion of the esophagus are injured, the emergency measures include eliminating the principal life-threatening symptoms, asphyxia, hemorrhaging, and dysphagia.

Therapeutic measures implemented in the presence of damage to the naso-pharynx immediately after trauma include quick control of bleeding coupled

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with antishock measures and prevention of aspiration of blood in the lower respiratory tract (the casualty must be laid with his face downward). The first step that must be taken in the presence of intense bleeding is pressing the carotid artery on the appropriate side against the spine or the first rib; this pressure must be maintained until the nasopharynx and nose are packed with tampons. If bleeding does not stop, the external and common carotid arteries must be exposed immediately, and that which, when subjected to pressure, stops the bleeding should be ligated.

When the oral and laryngeal divisions of the esophagus are wounded the priority task is to control bleeding and facilitate encumbered breathing. Bleeding can be stopped by applying a pressure bandage or by ligating vessels in the wound, and if bleeding is persistent, vessels are ligated throughout (the lingual and the external, inner, and even the common carotid arteries). Inasmuch as ligation of the internal or common carotid artery results in acute anemia of the corresponding half of the brain, it is justifiable only in the presence of life-threatening bleeding. Simultaneous ligation of the internal jugular vein and transfusion of large quantities of blood, plasma, and other blood substitutes is recommended as a means for reducing cerebral anemia.

Tracheotomy is one of the most radical measures against encumbered breathing when the esophagus is injured. By excluding an esophagus deformed by injury from the breathing act, tracheotomy also eliminates aspiration of blood from it. In addition removal of blood that had previously entered the trachea and bronchi is facilitated with the tracheotomic tube. If even after tracheotomy coughing does not sufficiently remove blood from the trachea and bronchi, as is evidenced by noisy, gurgling breathing, blood should be sucked out with a rubber catheter introduced into the tracheotomic opening as far as the bifurcation. In order to keep saliva and food from entering the wound area and the lower respiratory tract, the stomach probe should be introduced through the nose such that the casualty could be fed without swallowing movements. When extensive penetrating wounds are present the rubber tube is temporarily introduced not through the nose but rather through the wound and fixed in place with a bandage.

When the larynx is injured the therapeutic measures involved in first physician's aid include those indicated in the section discussing first aid to injuries of the middle and lower portions of the esophagus. When gaping wounds of the larynx are present, in some cases it would be possible to insert a tracheotomic tube into the larynx while simultaneously applying clamps to bleeding vessels. When the wound is too small for this measure, it would be suitable to enlarge it by dissection along the midline of the larynx.

When penetrating wounds of the trachea are present, bleeding is stopped and a tracheotomic tube is inserted through the wound with the help of a tracheal expander. If the wound is located laterally or low down or if its small dimensions do not permit this, a typical tracheotomy is performed.

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The following are sent for treatment directly to the ear, nose, and throat department of a specialized hospital during sorting at an OPM:

Victims with damage to the outer ear, the tympanic cavity, or the labyrinth, accompanied by hemorrhaging or suppurative discharge from the ear or the wound, impaired hearing, or total deafness on the side of the damaged ear, and vestibular symptoms (dizziness, ataxia, nausea, spontaneous nystagmus);

casualties with cranial injuries in the circumaural and frontal regions, coupled with damage to various divisions of the ear or the nasal sinuses;

casualties with injuries to the nose and its cavities or to nasal sinuses, without jaw fractures;

persons with neck wounds and injuries to neck organs (pharynx, larynx, esophagus, and trachea) not accompanied by spinal injuries and fracture of cervical vertebrae;

all casualties with a tracheostomy;

all persons with closed cranial injury or contusion exhibiting deafness, aphonia, numbness, or vestibular disturbances not accompanied by other neurological symptoms.

Specialized aid is provided in the ear, nose, and throat department of the main or neurosurgical hospital of the hospital base, and specialized therapy is continued until the final outcome is achieved. It involves all emergency specialized surgery, all stages of plastic surgery in accordance with the principles of otorhinolaryngology, and treatment of all stages of reactive inflammatory processes arising in response to injury--traumatic mastoiditis, sinus inflammation, phlegmon, perichondritis, osteomyelitis, and so on, as well as their secondary consequences--strictures, fistulas, and so on.

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CHAPTER 2

CHEST INJURIES

The frequency of chest wounds has varied in different wars. It has fluctuated rather significantly, not exceeding 12 percent of all wounds.

Chest injuries can be open (penetrating, nonpenetrating) or closed. In both cases they may be accompanied by injuries to internal organs--lungs, heart, vessels, and so on. Closed injuries can vary in severity. If only soft tissues are injured, such injuries are believed to be lighter. When injury occurs to bony formations--ribs, sternum, scapula, and so on--not to mention presence of accompanying injuries to thoracic internal organs, they are called severe injuries.

The severity of the wound process also depends on many conditions, to include the nature of the missile with which the wound was inflicted (bullet, shell fragment, secondary missiles--stones, parts of falling buildings, surrounding objects, and so on). The dimensions and location of the zone of injury as well as whether the wound is blind or through doubtlessly have significance.

Wounding of the central zone of the lungs is always more serious than wounding of the peripheral zone. Most casualties who had died on the battlefield had experienced wounds of major blood vessels and large bronchi.

Chest wounds may be simple and complicated--that is, accompanied by injuries to lungs and vessels of various sizes, and destruction of the bone system of the chest.

In cases where wounding of the chest and abdomen occurs simultaneously, such injury is called thoracoabdominal.

Open Injuries

The most constantly occurring signs of penetrating wounds of the rib cage, in the absence of an open pneumonthorax, are pains accompanying breathing, dyspnea, coughing, and hemoptysis. Hemothorax and pneumothorax are the principal symptoms of complicated chest injury. Hemothorax results from damage to a lung or vessels of the thoracic wall, when blood accumulates in significant quantities in the pleural cavity.

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Intrapleural hemorrhaging has been noted in 37.9 percent of chest wound cases not involving an open pneumothorax (A. A. Bocharov, 1949). Hemothoraxes are distinguished as small, medium, and large depending on the amount of blood draining into the pleural cavity. In the presence of a large hemothorax percussion reveals a dull sound over the entire half of the rib cage. Darkening of the entire pulmonary field and displacement of the mediastinum are revealed roentgenologically. A medium hemothorax is one in which the blood level is halfway up the scapula; with a small hemothorax it is below the middle of the scapula.

The location of intercostal arteries on the inner and lower inner surfaces of the ribs creates the condition for their injury also in the presence of closed chest traumas involving rib fractures, which can be accompanied by significant hemothorax.

A greater or lesser quantity of air can accumulate (pneumothorax) simultaneously with blood or without it in the pleural cavity after injury. Air can penetrate through the wound opening in the rib cage and from lung tissue injured by the wounding missile. Sometimes the quantity of air is negligible and pneumothorax can be revealed only by roentgenological analysis. Accumulation of a significant quantity of air in the pleural cavity is possible in the presence of a closed pneumothorax or an open but narrow wound channel. This results in tension or valvular pneumothorax, which not only completely collapses the injured lung but also considerably displaces the heart toward the opposite side and crowds the diaphragm downward (the mediastinal syndrome). Because of disturbances in breathing and cardiac activity arising as a result, the condition of such casualties becomes critical: The pulse rises abruptly, heart filling is poor, and the condition is aggravated by highly intense dyspnea and cyanosis.

Thus we distinguish between open, closed, and valvular (tension) pneumothorax.

Closed pneumothorax is encountered in about 25 percent of all cases. Presence of a moderate quantity of air does not by itself complicate the existing wound. If no other complications exist the air in the pleural cavity is usually resorbed in a few days.

The frequency of open pneumothorax depends on the percentage of shrapnel wounds. Air penetrates into the pleural cavity through the wound opening, causing the lung to collapse. During the breathing cycles of the rib cage the air freely enters the pleural cavity and exits from it at the time of expiration just as freely. For this reason the mediastinum and the major vessels and nerves within it are in a state of constant oscillation (floating of the mediastinum). The mediastinal oscillations are a cause of constant irritation of the sensory nerve apparatus, which leads to quickly developing and seriously proceeding shock aggravated by drastic impairment of gas exchange and circulation.

The larger the wound opening, the more sharply pronounced these phenomena are. If the dimensions of the hole in the thoracic wall are greater than

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the dimensions of the casualty's glottis, at the moment of inspiration air quickly fills the pleural cavity on the injured side, displaces the mediastinum in the opposite direction, and reduces the capacity of the healthy lung. Disturbance of external respiration--gas exchange--occurs. Oxidative processes are impaired, and phenomena of hypoxic hypoxia develop. When the wound hole is smaller than the dimensions of the glottis, less air penetrates through the wound on the thoracic wall than through the glottis, and for this reason lung ventilation is less disturbed and hypoxic phenomena are less pronounced.

When the wound hole is insignificant in size, small quantities of air penetrate into the pleural cavity during breathing. The air does not exit freely through the wound, being permitted inward only. These are the grounds for calling this a "sucking" wound in such cases.

Valvular pneumothorax arises when air gradually accumulates in the pleural cavity as it passes into the former through a hole in the rib cage or through a wounded bronchus. But because soft tissues produce a valve effect it cannot exit, as is the case with an open pneumothorax, and more and more air is pumped into the pleural cavity, displacing the mediastinum together with the heart and vessels in the opposite direction and pressing the diaphragm downward. Such valvular pneumothorax is also called tension pneumothorax. The patient's condition quickly becomes critical, and hypoxic phenomena become pronounced. Sharp dyspnea, cyanosis, and intense restlessness appear. The pulse quickens, and heart filling becomes poor.

A valve formed out of muscles of the thoracic wall does not lead to such a serious state, since after a moderate quantity of air accumulates in the pleural cavity, further entry of air through the wound opening in the thoracic wall ceases. Tension pneumothorax proceeds more seriously in the presence of bronchial wounds.

Air that has accumulated in the pleural cavity may penetrate through the wound opening in the thoracic wall into subcutaneous tissue and intermuscular spaces, causing subcutaneous emphysema. Subcutaneous emphysema is typified by swelling spreading through subcutaneous tissue for a greater or lesser distance around the wound hole in the thoracic wall, and by a crackling sensation when the thoracic wall is pressed with the fingers (crepitation).

The degree of subcutaneous emphysema can vary. In some cases presence of air in subcutaneous tissues can be detected only in the close vicinity of the wound opening. In other, severer cases it spreads from the injured half of the rib cage to its other half, the abdomen, neck, face, and limbs.

The frequency of this complication varies according to data of different authors, being about 25 percent on the average.

By itself, accumulation of air in subcutaneous tissue is not dangerous, since this air is resorbed in a few days and the swelling disappears.

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Mediastinal emphysema, which develops in the presence of wounds of the trachea and large bronchi, is a critical complication. In such cases air is pumped into the mediastinum, crushes major veins, and dramatically hinders passage of blood to the heart. When accumulation of air in the mediastinum is considerable, its emphysema may lead to death if surgical assistance is not provided promptly.

Shock and bleeding are the principal cause of early death from chest wounds. This requires the fastest possible implementation of the required first medical and first physician's aid and, in a number of cases, surgical intervention.

Closed Injuries

The lightest injuries are contusions of the rib cage not accompanied by damage to internal organs, while concussions, compression, and contusions of the chest coupled with injuries to thoracic organs proceed more severely.

Concussion of the lungs caused by an explosion can be observed in persons located near the point of the explosion. Autopsy of persons who had died as a result of such injury usually reveals rupture of alveoli and alveolar vessels. Rib fractures and external injuries may be absent in this case.

Compression of the rib cage is a result of sudden pressure on the chest. It causes rupture of pulmonary parenchyma together with all the resulting consequences.

Hemorrhaging into the lung may be extremely significant in this case, manifesting itself as severe respiratory insufficiency.

Greater bleeding in the presence of closed injuries to organs of the thoracic cavity is accompanied by profuse hemoptysis. The duration of pulmonary bleeding varies depending on the extent of injury--from several hours to 2-3 weeks. In addition to hemoptysis we can observe pain when breathing and limited breathing movements. When hemorrhaging into pulmonary parenchyma is extensive cyanosis develops and the pulse becomes thready.

Sudden intense and especially long-lasting compression of the rib cage causes the phenomena of so-called traumatic asphyxia, typified by a bluish violet color of skin in the upper half of the torso and mucous membranes. The shade of this color depends on the amount of bleeding resulting from sudden and sharp stagnation of blood within the system of the superior vena cava.

Rib cage compression and contusion is often accompanied by rib fracture. Fracture can occur either at the place where the force is applied, or elsewhere. In the first case the fragments penetrate inward and may cause damage not only to the parietal pleura but also to pulmonary tissue. When

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rib fracture occurs away from the point of application of the force--indirect fracture due to compression of the rib cage--the fragments usually tend to deflect outward. This may result in damage to soft tissues of the rib cage by sharp fragments of a rib end directed outward (compound rib fracture).

Ribs VI to X are usually the ones that are fractured when closed traumas of the rib cage occur. Symptoms of rib fracture include intense pain at the point of injury, intense pain sensations when breathing, shallow, occasionally faster breathing, and a strictly localized point of pain (corresponding to the place of rib injury) when the rib is palpated. When bone fragments are displaced, the symptom of crepitation of rib fragments can be determined by auscultation during inspiration and expiration.

When closed injuries of soft tissues and a lung are caused by bone fragments, complications such as hemothorax, pneumothorax, and subcutaneous emphysema may arise. Hemothorax is most highly pronounced with ruptures of intercostal vessels coupled with hemorrhaging into the pleural cavity.

The most serious form of rib fracture is multiple fractures. In this case up to 10-12 ribs may be injured on both sides.

Double rib fractures are very serious because in this case the conditions are created for floating (displacement) of a portion of the thoracic wall, taking the form of paradoxical respiration, which in turn causes growth in hypoxia.

Treatment of Chest Injuries

The measures implemented in first medical aid boil down to preventing the phenomena of shock, blood loss, and hypoxia. When open injuries are present it would be important to apply pressure bandages if bleeding occurs from the thoracic wall, apply sealing dressings in the presence of open pneumothorax, and administer painkilling and cardiac agents.

When closed injuries are present painkillers are administered, a pressure bandage is applied in cases of rib fractures, and the patient is placed in reclining position.

First physician's aid for open injuries involves achieving a Vishnevskiy vagosympathetic blockade, removing blood that had entered the pleural cavity with the goal of improving respiration, and preventing transition of a hemothorax or hemopneumothorax into a pyothorax or pyopneumothorax.

It has been demonstrated by Soviet authors (B. E. Linberg, 1960 and others) that the danger of resumption of bleeding after expansion of a wounded lung is negligible.

In the presence of an open pneumothorax the tightness of the occlusive bandage is checked. If the bandage is sound, the wound victim is evacuated

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to the specialized aid stage. When the occlusive bandage is not sound, surgical closure of the open pneumothorax would be indicated.

The operation is performed as initial surgical treatment: The wound margins are excised, and the wound channel is dissected, insuring sufficient access to permit wound inspection. Injured and cut vessels are ligated. Injured ribs are sutured, or rough edges are snipped off. Bone fragments are removed. After excision of the wound margins catgut sutures are applied to muscles layer by layer in two or three rows. In this case the surgeon should try to see that the suture lines are not directly above one another. The pleural cavity must be completely drained before tightening the sutures. Antiobiotics (penicillin, streptomycin) are introduced directly through the drain tube after the operation. If while suturing the pneumothorax a need arises for inspecting the pleural cavity and the lung, a standard thoracotomy is performed. Foreign particles are removed to the extent possible from the pleural cavity and wounded lung during surgical treatment. If bleeding from the lung is discovered, the lung is grasped with a soft clamp and drawn into the wound, after which the crushed edges are excised (following the principle of initial surgical treatment), and silk sutures are applied to the wound on the lung. In some cases pneumonopexy is indicated (suturing the lung to the parietal pleura).

If the wound opening in the thoracic wall cannot be closed with sutures by drawing soft tissues together, the wound should be covered over by a muscle panniculus on a broad pedicle from adjacent muscles, or a pneumonopexy should be performed. If it is impossible to suture a wound in the presence of an open pneumothorax, it should be packed with a tampon covered with Vishnevskiy's ointment.

Blood that had drained into the pleural cavity and accumulated there should be removed from the pleural cavity through a drain tube in all casualties after an open pneumothorax is closed. Expansion of the lung creates the conditions for the fastest possible recovery of normal breathing and circulation. Removal of the contents of the pleural cavity is the principal means for preventing pleural infectious complications.

When a tension pneumothorax is present, a large needle (the sort used for blood transfusions) should be introduced as an emergency measure into the seventh intercostal space along the dorsal axillary line. A drain tube to which the finger of a rubber glove, cut slightly at the tip, is secured should be placed over the outer end of the needle. Upon expiration, this valve opens and admits air accumulated in the pleural cavity, and upon inspiration it closes, preventing outside air from penetrating into the pleural cavity. The drain tube is secured to the skin with silk thread. This immediately improves the condition of the victim.

Closed injuries requiring first physician's aid include rib fractures, crushing of the chest, and injuries to organs of the thoracic cavity.

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Rib fractures are treated with a blockade of intercostal nerves supplying the injured ribs using 0.5 percent novocaine solution. Novocaine should also be injected in the intercostal spaces one rib above and below the place of fracture. After such a novocaine blockade pain sensations usually decrease significantly or even disappear entirely, breathing becomes fuller, and the condition of the casualty improves dramatically.

Paravertebral blockade also produces a good impact.

When ribs are fractured at their ends, immobilization of the floating section with a plastic strip with holes (the Vityugov-Aybabin method) is effective.

Tracheostomy is indicated in the presence of multiple rib fractures; emergency thoracotomy is indicated in the presence of open injury to the chest accompanied by phenomena of quickly growing mediastinal emphysema (occurring with rupture of a major bronchus).

Heart Injuries

Cases of heart injuries are encountered very rarely, since the bulk of such casualties die.

When cardiac tamponade phenomena are present the pulse cannot be felt in peripheral arteries, or the rapid pulse of weak heart filling is detected. In some rarer cases the pulse is slow. The victim develops intense dyspnea, cyanosis, and high restlessness. The dimensions of the blunt tip of the heart are significantly enlarged. Heart tones are dull, and sometimes barely audible.

Surgical aid entails immediate exposure of the heart and application of sutures on the heart wound. The operation requires swiftness; this is why opening the pleural cavity with an intercostal incision at the fourth or fifth intercostal space is recommended. Silk sutures are applied to the heart. The pericardium is stitched together with occasional sutures, and collected blood would best be transfused back into the patient.

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CHAPTER 3

ABDOMINAL INJURIES

Injuries to the abdomen and its organs were encountered in 2 to 7 percent of all cases in the Great Patriotic War depending on battle conditions. There were both closed and open--gunshot--injuries; wounds made by silent weapons were rarely observed.

Closed Injuries

In comparison with open injuries, the proportion of closed injuries was small, being 3-5 percent of all abdominal injuries. They were encountered mainly as a result of falls, the action of direct blows and counterblows, the effects of explosive air and water waves, and so on.

Closed abdominal traumas include contusions of the peritoneum, sometimes with significant bleeding into the body of muscles and even rupture of individual muscle groups, and closed injuries to organs of the peritoneal cavity--parenchymatous (spleen, liver, pancreas) and hollow organs (stomach, intestine, gallbladder, urinary bladder). Shock and blood loss often accompany injuries to abdominal organs.

Peritonitis may develop in the first hours following trauma. The danger of peritonitis is especially great with ruptures of the gastrointestinal tract and the urinary bladder, and when secretions from injured parenchymatous organs enter the peritoneal cavity, for example bile due to rupture of the liver and gall bladder.

Identification: Clarifying the circumstances--that is, the anamnesis--surrounding closed abdominal traumas has extremely important significance to establishing the diagnosis.

Presence of trauma dominated by contusion of some division of the abdomen or another provides an indication to the physician as to the direction his thoughts should go in order to clarify the causes of a serious condition.

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Anamnestic data are confirmed by the results of examination and analysis, which must be performed systematically and consistently. The data of the initial analysis must be recorded on the accompanying documents or the initial casualty accounting medical card. This affords a possibility for comparing these data in the following stage with the data obtained from a later examination.

According to data from the Great Patriotic War (I. A. Krivorotov, 1949), injuries accompanying closed traumas of internal organs were encountered in the following ratios: Intestine--33.3 percent, spleen--15.4 percent, kidneys--16.7 percent, liver--16.3 percent, urinary bladder--16 percent, stomach--6 percent, and pancreas--1.6 percent.

One should not wait for the entire set of symptoms to appear before making a diagnosis of injuries to some internal organ in the presence of closed trauma, since such a diagnosis would only be possible in later stages of the process. The one question that must be answered is: Is there or is there not damage to internal organs? If the answer to this question is positive, we must immediately answer a second question: What is the cause of the victim's serious condition--shock, blood loss, or both? The answer to this question predetermines the surgeon's subsequent tactics. If shock is present he must first of all implement all antishock measures, and the time spent on these measures will be enough to permit more-definite differential diagnosis based on dynamic observation.

When blood loss occurs, the surgeon must not lose time on dynamic observations and achieve control of blood loss by blood transfusion. He must immediately perform a laparotomy and halt bleeding. A diagnosis of closed injuries to internal organs can be established much more quickly after performing a laparotomy. According to A. N. Berkutov this is the simplest method for determining presence of intraperitoneal bleeding.

In uncertain situations, when it is difficult to determine the nature of the main injury, the surgeon must begin with antishock measures, and if they do not produce an effect he would have to hypothesize presence of unchecked hemorrhaging, and begin surgery.

Rupture of a parenchymatous organ may manifest itself first only as shock and tension of abdominal muscles in the area of injury, to which the symptoms of internal hemorrhaging are gradually added--the victim's restlessness, growing pallor, thirst, faster pulse. In serious cases of blood loss we observe frequent, weak heart filling, sometimes even a thready pulse, pronounced pallor, restlessness, shallow breathing, and ebbing consciousness. Percussion (with the victim on his back) reveals dull sounds in the sloping areas of the abdominal cavity.

When bleeding in the peritoneal cavity is profuse and shock phenomena are dramatically pronounced, tension may be absent from peritoneal muscles.

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The general symptoms of bleeding are rather clearly pronounced in the presence of spleen ruptures. The victim is pale, and his pulse is rapid and weak. The peritoneal irritation symptom appears quickly. Palpation of the abdomen reveals pronounced rigidity of muscles on the left half of the abdomen. Usually in the presence of an injured spleen casualties complain of pain in the left half of the rib cage as well as an irradiation of pains into the left shoulder and clavicle. The victim feels pain when pressure is applied over the inner end of the left clavicle. Percussion reveals presence of exudate in sloping portions of the abdomen. The victims usually lie on the left side or sit, pressing the thigh to the abdomen. When an attempt is made to place them on their back or on the other side, they immediately assume the former position, stating that otherwise they cannot breathe. The stubborn desire of the patients to return to their initial position after a change is extremely typical of a ruptured spleen.

In some cases, when abdominal traumas are caused by dull objects, subcapsular rupture of the spleen may occur. This injury is accompanied by dramatically pronounced symptoms, and it often proceeds unnoticed. Later, however, secondary rupture of the capsule may occur about a hematoma, resulting in sudden and rather quickly progressive worsening of the victim's condition. Pallor, cold sweat, a drop in pulse, and irradiation of pains into the clavicle make the diagnosis undoubtable. All of this can happen within a few hours or days after trauma, even as a result of insignificant repeat traumatization (sneezing, coughing, and so on).

Shock phenomena dominate with a ruptured liver. Hemorrhaging is not as sharply pronounced as with a ruptured spleen. Muscle tension can be sensed in the upper regions of the right half of the abdomen. Because liver ruptures are accompanied by rupture of not only blood vessels but also the bile ducts, the symptoms of peritoneal irritation soon arise--vomiting, peritoneal muscle tension and Shchetkin's symptom.

Closed injuries of the pancreas are extremely rare. Injury of the glandular matter itself does not produce significant bleeding, but shock phenomena can be sharply pronounced. Pains are located in the upper part of the abdomen, irradiating into the back. Serious peritoneal phenomena develop in the subsequent periods, when pancreatic juice enters the cellular tissue and the peritoneal cavity. The victim's general condition worsens dramatically as a result, and peritonitis phenomena appear--tympanites, repeated vomiting, a rapid, weak pulse, and so on.

Ruptures of hollow organs in the peritoneal cavity are dangerous mainly because they lead to general peritonitis. If rupture is not accompanied by profuse bleeding from torn vessels of the mesentery, the diagnosis is almost always established when symptoms of peritoneal irritation are present--that is, when peritonitis has already developed. The higher up the gastrointestinal tract the hollow organ ruptured, the more quickly the peritonitis develops. Pain is always an accompanying symptom.

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Ruptures of the stomach and intestines resulting from crushing of the abdomen spread over a long distance, which is accompanied by extremely serious phenomena, the symptoms of sharp irritation of the peritoneum being dominant. In these cases victims rescued immediately after trauma are in a state of more or less sharply pronounced shock. At the same time we can clearly observe a peritoneal reaction typified mainly by pains and pronounced tension of abdominal muscles. Muscle tension can be established by light palpation of the peritoneum. First it can be detected in the area of injury, but later, as the contents of the gastrointestinal tract and inflammatory exudate collect in other areas, it spreads gradually over the entire abdomen. Muscle tension can also be seen when examining the victim. The abdominal muscles do not participate in breathing at all: The latter is much more superficial than normal, occurring only due to movement of the rib cage, and not the diaphragm. The abdomen, which remains still while breathing motions occur, is drawn inward at first. And it is only later, after constantly increasing tympanites appears, that the distended abdomen typical of diffuse peritonitis develops.

A positive Shchetkin-Blyumberg symptom confirms peritoneal irritation.

Percussion might reveal disappearance of hepatic dullness, which is observed when gas penetrating from the stomach or intestine accumulates in the peritoneal cavity. This same method can be used to determine accumulation of fluid (exudate or blood) in sloping portions of the abdomen.

Auscultation can be employed to determine presence or absence of intestinal sounds. Development of peritonitis quickly leads to intestinal paresis, presence of which is established by disappearance of peristaltic intestinal noises.

Immediately after abdominal trauma accompanied by injury to hollow organs (if shock phenomena do not exist), the pulse remains unchanged. Bradycardia may even be observed at first. But later, as peritonitis phenomena develop, the pulse rate rises.

First medical aid must include maximum rest for the victim; he must not be allowed to either eat or drink in the presence of the slightest suspicion of injury to the gastrointestinal tract. No medicines should be administered *per os*. Morphine is contraindicated in cases where the diagnosis of injury is unclear, but it would doubtlessly be required in the presence of abdominal injuries when the diagnosis has already been established. First physician's aid entails emergency laparotomy, inspection of organs in the peritoneal cavity, and elimination of discovered pathology.

Before the operation, during it, and after the operation blood, plasma, anti-shock solutions, and so on must be infused into the victim in order to fight and prevent shock and control blood loss.

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Open Injuries

These can be penetrating and nonpenetrating, blind and through, gunshot, nongunshot (made with silent weapons and secondary missiles), single and multiple, and combined (including thoracoabdominal).

Identification: Nonpenetrating abdominal wounds are usually not serious. Only those nonpenetrating abdominal wounds in the presence of which contusions and even ruptures of intraperitoneal organs, particularly the intestine, associated with the force of a bullet's or fragment's lateral shock, are observed, are serious.

It is not always possible to differentiate nonpenetrating from penetrating wounds. In doubtful cases the surgeon must excise or dissect the wound layer by layer, and during its treatment precisely determine whether or not it penetrates into the peritoneal cavity. If the peritoneum is whole--that is, if it is a nonpenetrating wound, therapy follows the rules of treatment of soft tissue wounds (if symptoms of injury to peritoneal organs are absent). When the integrity of the peritoneum is disturbed, a laparotomy should be performed and the peritoneal cavity and its organs should be subjected to detailed examination.

Penetrating Wounds

A bullet or shell fragment penetrating into the peritoneal cavity often inflicts multiple wounds. Prior to the operation, it is not always possible to establish which organs might be injured or wounded. This can be done easier with through wounds, when wounding of a particular organ might be hypothesized from the path of the wound channel.

The symptoms accompanying penetrating wounds of the peritoneal cavity--general and local--depend on the nature and degree of the injuries. Theoretically, internal hemorrhaging would have to be the dominant symptom accompanying wounds of parenchymatous organs, while symptoms of peritoneal irritation would occur with gunshot injuries to hollow organs. But this is not always so. Isolated injuries are not encountered that often. Bleeding may be clearly pronounced with wounds of hollow organs. Considering the seriousness of the course of wounds of the peritoneal cavity, we cannot wait around for serious symptoms to develop so that a diagnosis of a penetrating wound could be confidently established. This is why there can only be one tactic in relation to not only clearly evident penetrating wounds of the peritoneal cavity but also suspected ones--early surgery.

Diagnostic difficulties arise with blind wounds. In these cases the diagnosis is undebatable when the omentum or some organ of the peritoneal cavity protrudes through the wound, or when clear peritoneal symptoms are present. It is difficult to establish a diagnosis when the wound openings are far away from the abdominal wall (the buttocks, the upper thigh, and so on). In view of this, every wound and, all the more so, blind wounds in

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the vicinity of the abdomen, buttocks, and pelvis should be suspected to be penetrating abdominal wounds.

The conclusive diagnosis is made on the basis of the clinical pattern--abdominal pains, sharp painfulness in response to palpation of the abdomen and tensing of its muscles, a sharply expressed Shchetkin-Blyumberg symptom, absence of abdominal breathing, and absence of intestinal peristalsis (established by auscultation). The pulse is rapid. Peritonitis phenomena develop gradually. The tongue becomes dry. Temperature rises, vomiting begins, and leukocytosis is sharply pronounced (up to 20,000-30,000), with the leukocyte formula shifting leftward. Rectal examination reveals only sharply pronounced painfulness in the vicinity of the pouch of Douglas in the initial stages. Urination is inhibited, and diuresis low.

Treatment of patients with wounds of the peritoneal cavity should begin as soon as possible. It must be general and local.

Considering that the viscera may easily fall out through the defect formed in the abdominal wall by shell fragments and secondary missiles produced by a nuclear burst, a bandage should be wound around all casualties with penetrating wounds of the peritoneal cavity when first aid is rendered. Administration of narcotics is prohibited. Casualties with abdominal wounds are transported on stretchers with the legs bent at the hip and knee joints. The most comfortable evacuation resources should be used.

First physician's aid entails providing complete rest to the victim, aiding his recovery from shock, and replenishing lost blood. Symptomatic therapy is provided in accordance with the indications. Exposed viscera are bound in gauze napkins, after which the skin around the wound is wiped with alcohol, followed by an application of iodonate.

Specific Features of Surgical Intervention

All penetrating abdominal wounds require immediate surgery. We must guide ourselves by a fundamental principle in this case: The sooner the operation is performed, the better the results.

During the Great Patriotic War up to 90 percent of the casualties with abdominal wounds were brought to the main physician's aid stage in a state of shock (N. N. Yelanskiy, 1951). It would be better to operate on such casualties after they recover from shock, though this is not always possible when hemorrhaging persists. This is why surgery must be performed on this group of casualties on the basis of vital indications, in conjunction with massive blood transfusions.

Blood transfusion should precede every laparotomy, and it should continue during the operation and after it. A satisfactory condition exhibited by casualties with penetrating wounds must not serve as the grounds for postponing surgery or, all the more so, canceling it.

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An agonal condition--absence of consciousness and pulse, superficial breathing--is a contraindication to surgery.

The first casualties selected for surgery are those exhibiting hemorrhaging and prolapsed viscera.

Anesthesia provided during surgery involving organs of the peritoneal cavity must fully insure relaxation of abdominal muscles. Anesthesia would best be provided promptly. Local anesthesia can be provided by A. V. Vishnevskiy's method. Whatever the form of anesthesia employed, novocaine solution should be injected beneath the peritoneum and into the root of the mesentery immediately after the peritoneal cavity is opened. Median laparotomy is the technique employed most often. It must be sufficiently wide, to permit an examination of the peritoneal cavity and assessment of existing injuries. If need be, the cut could be widened to the right or left. If the cut crosses the wound opening, the wound channel should be excised. If the cavity must be drained, tampons and drain tubes should be introduced not through the surgical wound but rather through specially made openings.

When examining the organs of the peritoneal cavity the surgeon first searches for the source of bleeding and stops it.

When wounds are present on the front of the abdomen, the rear wall should be examined as well. Abdominal wounds are closed with a double-row suture.

The intestine could be injured in several places. Sometimes a significant length of the mesentery is torn away from the intestine. The entire length of the intestine should be examined, though gradually, without drawing significant lengths of it out of the wound. When the injured loop of the intestine is discovered, each wound opening must be carefully closed with gauze napkins, intestinal clamps should be applied, and after this adjacent divisions should be inspected; the latter might be considerably more damaged, which would require resection of a portion of the intestine. When there are multiple injuries of the intestine it would be more profitable to resect one large section of intestine than to resect two sections in two adjacent places.

When possible, an attempt should be made to close intestinal wounds with transverse double-row sutures (to avoid making the intestine narrower). Resection of the intestine should be resorted to only if the intestinal loop is significantly damaged or torn from the mesentery. Intestinal resection, which is one of the more serious operations, produces much poorer results in wound victims. In the event that the omentum and intestinal loops prolapse through the wound, the prolapsed omentum should be resected. Prolapsed intestine is examined, washed with physiological solution (using gauze napkins) and, if it is not injured, returned into the peritoneal cavity. If the laparotomy is performed later, when the signs of peritonitis appear, the intestine must not be resected. It would be better to draw the wounded portion out into the open.

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When injuries occur to the large intestine, only spot wounds are sutured. If significant damage occurs to the large intestine, the simplest operation is performed--withdrawing the wounded section through a separate cut and securing it with frequent sutures to the peritoneum (intestinal fistula). In this case the peritoneum must be meticulously sutured to the skin around the entire circumference of the withdrawn intestinal loop to avoid formation of an intestinal phlegmon in the wound area. If the intestine is torn completely apart transversely, after the mesentery is separated from the wall of the intestine, its two ends are stitched into the wound in the area of uninjured portions of the intestine using a double-barreled suture, after which the injured portion of the intestine is excised. Leaving an injured intestinal loop outside the peritoneal cavity usually leads to ascending thrombophlebitis of its mesentery.

When wounds are present in the dorsal or dorsolateral areas of the abdomen, retroperitoneal injuries of the large intestine are possible. Sometimes one of the wound openings is on the surface of the large intestine, covered by the peritoneum, while the other is on its rear surface, not covered by the peritoneum. In such cases the wound on the anterior surface of the intestine is sutured shut, and a tampon or drain tube is introduced into this place from the dorsal or dorsolateral wall of the intestine. To preclude development of life-threatening retroperitoneal phlegmons in the presence of retroperitoneal wounds of the large intestine, the wound on the dorsolateral surface of the abdomen must be meticulously treated, and it must be left broadly gaping. The surgeon must not forget to create a stoma on the appendix to provide relief to the large intestine.

Hepatic wounds of even small size can be accompanied by significant blood loss. If a laparotomy is performed on the midline of the abdomen and this is found to not provide sufficient access to a hepatic wound, an additional transverse cut should be made through the rectus abdominis muscle or along the costal arch. Bleeding from the liver is stopped by applying (obkalyvayushchiye) catgut sutures. When extensive hepatic wounds are present and bleeding cannot be stopped with sutures alone, the wound should be tamponed with a mesenteric panniculus on a pedicle and above it the wound in the liver is sutured together. When sutures are applied the margins of the hepatic wound should be dissected to the extent possible. In this case tissue should not be excised from deep within the wound to avoid injuring major blood vessels and bile ducts in hepatic tissue.

When bleeding from hepatic wounds is significant, compression of the hepatoduodenal ligament can be recommended as a temporary means for stopping bleeding. In this case the index finger of the left hand is inserted into the foramen of Winslow beneath the ligament, which is then pressed between the thumb and index finger. The ligament can be pinched with a soft clamp bearing rubber tubes on its jaws. The ligament must be pinched gently, for not longer than 10-15 minutes. During this time the margins of the hepatic wound could be dissected, and several sutures could be applied. When pressure no longer need be applied to the ligament additional sutures are applied in those places where bleeding is not completely stopped.

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When wounds are present on the upper surface of the right lobe of the liver, in which case it is difficult to apply hemostatic sutures, an attempt should be made to stop bleeding by stitching the free margin of the liver to the parietal peritoneum (Alferov's hepatopexy). When the liver is anchored in this way, the hepatic wound presses firmly against the diaphragm, and bleeding stops.

A hemostatic sponge can be used to stop bleeding from parenchymatous organs, the liver in particular.

In the presence of hepatic wounds, when bleeding from the liver is completely stopped with sutures and blood spilling into the peritoneal cavity is removed, the abdominal wound can be sutured shut. But when there are extensive injuries to the liver, when the liver wound was tamponed by the omentum, and when seepage of blood and, all the more so, bile from injured bile ducts after application of sutures is possible, a tampon and drain tube should be introduced as far as the hepatic wound; the ends of the tampon and drain tube are led outward closer to the outer corner of the skin wound, when a transverse incision is employed. In the case of a midline incision the drain tube is introduced through a separate cut.

When very severe wounds are present and the time of the operation must be reduced to a minimum, bleeding from a hepatic wound can be stopped by tamponing the wound with a long gauze tampon. But when tamponing the liver the surgeon should remember that an excessively rough procedure could inflict even greater injury, since liver tissue tears easily in such cases. The tampon is introduced through a separate incision on the abdominal wall.

The surgical tactics used in relation to wounds of the spleen are the same as for closed ruptures of the spleen, requiring a splenectomy.

When closed ruptures of the spleen, liver, and mesenteric vessels occur and isolated wounds are present, it would be a great mistake not to utilize blood spilled into the peritoneal cavity for autotransfusion (blood spilled into the peritoneal cavity can be transfused into the same victim). For this purpose after the peritoneal cavity is opened, blood is bailed out with a large spoon (an ordinary tablespoon can be used) and collected in a previously prepared vessel attached to a transfusion system. The blood must be filtered through eight layers of gauze to keep out clots. The vessel is first filled with 200-300 ml physiological solution and 5 percent freshly prepared sodium citrate solution at a rate of 2-3 ml solution for every 100 ml blood.

Blood that had spilled into the serous cavity in the presence of concurrent wounds of hollow organs cannot be transfused back into the patient.

When blind wounds are present in the peritoneal cavity, only those foreign particles which are easily detected during surgery are removed. The

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operation should not be lengthened by a special search for foreign particles. If possible, roentgenography should be performed prior to surgery involving blind wounds.

The postoperative period: During the first days following surgery on abdominal organs, massive dropwise (hypodermic, intravenous) infusions should be made of physiological solution and 5 percent glucose solution--up to 3-4 liters per day; blood transfusions should also be made. If possible, blood should be transfused daily--250 ml, or plasma at 100 ml.

The patient should be in reclining position or, if possible, with the head end of the bed raised and with a cylinder placed beneath the knees. A permanent suction tube should be introduced to evacuate stomach contents in the presence of gastric paresis and repeated vomiting. A thin gastric probe is inserted through the nose (after lubricating the nasal passage and naso-pharynx with 3 percent cocaine solution), and it is left there for constant suction of stomach contents. To keep the probe from slipping out it is anchored down to the wing of the nose with adhesive tape. When suction is provided constantly, the patient can be allowed to drink in unlimited quantities.

Wound victims require absolute quiet following laparotomy. Therefore if the operation had been performed at an OPM and due to circumstances the patient must be transported to the nearest therapeutic institution, this should be done not earlier than the 2d or 3d day after the operation, and with maximum caution.

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CHAPTER 4

INJURIES OF THE PELVIS AND THE PELVIC ORGANS

Gunshot wounds of the pelvis made up 3.8-4.5 percent of all wound cases in the Great Patriotic War. Wounds in the pelvic area made up 14.2 percent of all soft tissue wounds. Pelvic traumas were encountered among 2.7 percent of all casualties subjected to shock waves caused by bombs; 26 percent of these casualties suffered fractures of pelvic bones, complicated by traumatic shock as a rule. Out of the total number of casualties receiving pelvic injuries during bombing raids, 65 percent required surgery. Complications, usually suppuration, were observed among 43 percent of the casualties.

Injuries to Pelvic Soft Tissues

Isolated injuries to soft tissues surrounding the pelvic girdle do not differ fundamentally from wounds in other anatomical regions.

Wounds accompanied by injuries to the superior gluteal artery, which can be identified by arterial hemorrhaging or a progressive, sometimes pulsating hematoma, and by stretching pains in the buttocks, offer the greatest danger.

There is also practical significance to traumatic detachment of skin and stressed hematomas formed in the bodies of muscles following injury to small arteries and impairment of blood coagulation. These hematomas are characterized by swelling, the feel of stressed tissues, stretching pains and, sometimes, symptoms of nerve trunk compression.

Traumatic tissue detachment is a product of tangential injuries, and it can be extremely extensive, spreading more often to the thigh and waist. Blood and lymph accumulate, in significant quantities on occasion (up to 1 liter) between subcutaneous cellular tissue and the skin on one hand and fasciae and muscles on the other. When not drained in time, such accumulations can cause necrosis of detached skin and suppuration typified by a long healing time.

Treatment: In the presence of contusion--rest, cold; in the presence of injuries to gluteal arteries--ligation of the vessel in the wound or of the

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internal iliac artery; in the presence of open wounds--surgical treatment. Stressed hematomas are punctured or resected. In the latter case a thin drain tube is introduced. In both methods of evacuation, a cotton-gauze pressure bandage is applied and drugs promoting hemostasis are prescribed. Detached skin is pressed firmly with a cotton-gauze dressing for the time required for firm adhesion of the panniculus. When suppuration develops, dissection of the abscess and itsdependable drainage are indicated. When necrosis of a sloughed panniculus is significant, excision of necrotic tissues and closure of the wound with local tissues and a panniculus cut with a dermatome would be the most sensible.

Pelvic Bone Fractures

Injuries to pelvic bones are usually the consequences of blows from objects in the pelvic area, the dropping of objects onto the pelvic area, crushing of the pelvis in anteroposterior, transverse, or oblique directions, or successive compression of the pelvis in different directions ("rolling"). This results in simple pelvic bone fractures, communicating compound fractures (the bone wound communicates directly with the outside through the soft tissue wound), and noncommunicating compound fractures (the places of bone fractures do not coincide with skin wounds).

In view of close anatomical mutual relationships, pelvic organs may be injured concurrently with fractures of pelvic bones. Injuries to the urethra, the urinary bladder, and the rectum are the most dangerous.

The possibility of multiple combined pelvic fractures grows with the use of thermonuclear weapons.

Classification: The simplest classifications suited to stages of both specialized and first physician's aid, but ones which at the same time distinguish practically important features between individual groups of casualties, have advantages in the face of a massive arrival of casualties. Thus it would be sufficient to subdivide all injuries of the pelvis into four groups (Figure 12).

1. Fractures that do not disturb the integrity (continuity) of the pelvic girdle. The supporting function of the pelvic girdle persists in the presence of these fractures.

2. Fractures disturbing the integrity (continuity) of the pelvic girdle (anterior, posterior, and mixed--unilateral, bilateral, diagonal).

3. Transacetabular fractures (marginal, dislocation fractures, and combined fractures and subluxations).

4. Dislocations and dislocation fractures (in the pubic and sacroiliac articulations).

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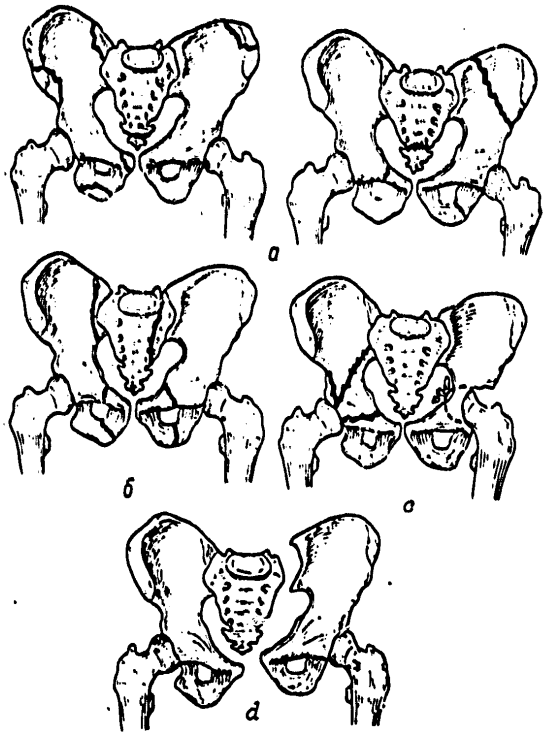

Figure 12. Variants of Bone Fractures: *a*--bone fractures without disturbance of the pelvic girdle's continuity; *b*--fractures disturbing the pelvic girdle's continuity; *c*--transacetabular fractures; *d*--dislocation fracture and dislocation of pelvic bones

Combined injuries to pelvic bones are subdivided into the following groups:

1. Pelvic fractures combined with nonpenetrating injuries to the urinary bladder and urethra.

2. Pelvic fractures combined with penetrating injuries to the urinary bladder and urethra.

3. Pelvic fractures combined with penetrating rectal injuries.

4. Pelvic fractures combined with injuries to organs of the peritoneal cavity, chest, spine and spinal cord, skull and brain, and limbs.

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5. Combined pelvic fractures (combining with burns, radiation sickness, radioactive contamination, war gas contamination).

Clinical pattern: The degree to which clinical manifestations are expressed in the presence of pelvic fractures depends on both the location, nature, and extent of the fractures themselves, and on the victim's individual sensitivity to pain, his general condition, presence or absence of other injuries, and medical aid rendered previously.

When fractures occur without disturbance of the pelvic girdle, pains are usually located in the area of the fracture. Tensing of muscles attached to the broken fragment causes pain to increase. Thus, for example, in the presence of a fracture of the ischium, pain arises both with palpation of the injured bone and with tensing or stretching of adductor muscles (abduction of the thigh). When the anterior superior spine of the ilium breaks away, pain is produced by tensing of the sartorius muscle, owing to which victims sometimes prefer to move backward (Lozinskiy's or "retrograde" symptom). When the superior ramus of the pubis is fractured, flexion of a straightened leg at the coxofemoral joint is impossible due to the pain, and the victim draws it up tightly, shuffling his heel about the bed, but when the leg is passively drawn up the victim keeps it there (the lumboiliac muscle stops pressing on the pubis, or traumatization of this muscle by the bone fragment ceases), which has come to be called the "stuck heel" symptom. Pain accompanies tensing of the obliquus abdominis muscles in the presence of fractures of the crest of the ilium, of the sacrospinalis muscles in the presence of a fracture of the posterior superior spine of the ilium, of muscles of the pelvic diaphragm in the presence of a dislocation fracture of the coccyx, and so on.

When the patient has a fracture on the wing of the ilium he moves about leaning sideways for the same reasons. Palpation of injured portions of these bones is painful, but pressure on the pelvic girdle outside the zone of injured areas does not elicit pain. Hematomas are usually small, and if they do become visible beneath the skin, they do so after 3-5 days.

Fractures coupled with disturbance of the continuity of the pelvic girdle exhibit clearer symptoms due to impairment of supporting functions, a pattern of significant blood loss, and pronounced spontaneous and provoked pain. Traumatic shock often develops. Victims lose their ability to move about independently.

When double vertical fractures occur, the lateral portions of the pelvis shift proximally together with the lower limbs (due to the pull of abdominal muscles and the quadratus femoris) and rotate outward (due to the pull of the gluteus maximus muscle). The victim assumes a position with the limbs partially bent, spread, and rotated outward (the "frog position," Volkovich's symptom). Pain is elicited by palpation of the anterior and posterior divisions of the pelvic girdle. Attempts at tensing muscles of the torso

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and lower limbs attaching to the pelvis are painful. Pain arises in response to an attempt to raise the upper part of the torso (in response to coughing, tensing of the peritoneum, and its palpation). Signs of blood loss are pronounced. The protruding ends of the bone fragment can be determined by palpation. In the very first hours hematomas may be visible in the inguinal and sacroglutæal regions. Peritoneal symptoms are possible owing to irritation of the parietal peritoneum by a retroperitoneal hematoma (the "pseudoperitoneal syndrome"), and reflex urine retention is often observed.

These symptoms are on the side of injury in the presence of unilateral vertical pelvic fractures.

The size and location of intrapelvic and preperitoneal hematomas may be revealed tentatively by the dulling of the percussion note above them and by palpation through the rectum.

When diagonal fractures of the pelvis occur, in which case the fracture on the anterior division of the pelvic girdle is located on one side while that on the posterior division is located on the opposite, not only the entire lateral part of the pelvis from the plane of the posterior fracture but also the median fragment of the anterior division on the side of the anterior fracture shift proximally. The locations of painful areas coincide with fracture locations. Once again if displacement occurs, asymmetry can be revealed in the locations of the right and left halves of the pelvis.

If the symptoms listed here are still not enough for a precise diagnosis and the condition of the casualty permits, we can employ other diagnostic procedures based on pain sensations at the place of the fracture in response to gentle pressure upon the pelvic girdle. The latter is achieved by lightly pressing the pelvis beyond the crests of the ilium, applying a displacing pressure to the crests of the ilium, applying pressure between the crest of the ilium and the ischial tuberosity, or by tapping the heel of the straightened leg.

Irrespective of the form and degree of injury, transacetabular fractures of the pelvis are accompanied by injury to the articular cartilage, and they create the danger of subsequent complications (contracture, ankylosis, osteo-arthritis deformans). The greater the degree of injury, the more frequently complications develop, especially when fractures are compounded by dis-placement of fragments, dislocation of the femur from the acetabulum, and central displacement of the capitulum of the femur into the pelvis (central subluxation, dislocation).

Symptoms of such injuries are associated with impairment of active joint function, pain in response to attempts at passive movement and palpation of the joint, and pain in response to light tapping of the greater trochanter, tapping of the heel, and compression of the pelvis by pressure upon the greater trochanters.

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If the acetabular fracture is accompanied by dislocation of the femur, the limb assumes the typical position corresponding to a dislocation. Palpation through the rectum reveals pain and pastiness in the area of the fracture and, on occasion, crepitation of the fragments.

Dislocation fractures arise when pelvic bones separate in the pubic and sacroiliac joints. In the presence of a dislocation, the corresponding half of the pelvis and the lower limb usually shift proximally and rearward, recalling the clinical symptoms accompanying a unilateral vertical fracture. But the proximal displacement may be absent, and the rearward displacement may not exceed that of a subluxation, though the ligament system would be destroyed and the pelvis would be unable to perform its supporting function.

When displacements are absent or if displacement occurs rearward only, the clinical pattern is indistinct. The physician can be aided in making a correct diagnosis by revealing areas of pain through palpation and application of pressure in the area of the symphysis and sacroiliac joint, in response to tapping of the heel of the straightened leg on the healthy side, and in response to compression and separation of the pelvis by pressure upon the crests of the iliac bones. Pain arises in the the sacroiliac joint in response to inward rotation of the thigh, flexed in the coxofemoral and knee joints, owing to tension of the piriformis and psoas muscles, and sometimes in response to adduction or abduction of the thigh, bent in the coxofemoral joint.

When gross displacements are present, we can easily see deformation in the area of the symphysis, asymmetry of the location of the posterior superior spines of the ilium and, on occasion, rearward protrusion of the sacral bone.

Sometimes when the ligament system is not completely ruptured, the victim can move about. Tension of deep back muscles becomes noticeable at this time, pain arises in response to straightening of the torso, and disappearance of the lumbar curvature, curving of the spine in the opposite direction, and the inability to take a long step with the healthy leg or rise quickly from a seated position are noted.

When there is concurrent injury to pelvic organs, the clinical complex of pelvic fracture symptoms is compounded by signs of injury to the appropriate organ.

Clinical Pattern of Injuries to Pelvic Organs

Injury to the urethra is typified by discharge of blood from it apart from the act of urination, pain in the injured area, hematomas, and dysuric phenomena (inability to urinate, cutting pains in the perineum or the penis in response to attempts at urination, urination in a discontinued

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stream, often coupled with initial hematuria, and increasing overfilling of the urinary bladder). Ruptures usually arise in the membranous urethra in men in the presence of pelvic fractures. When rupture of the posterior urethra occurs, the pelvic diaphragm is usually damaged and urinary infiltrate spreads both proximally into cellular tissue around the bladder, and distally, into the perineal tissue. Urinary phlegmons develop later in the pelvis. Palpation through the rectum may reveal swelling of the testes and painfulness in the area of urethral injury. A perineal urohematoma can often be detected within the first hours. The urethra is usually injured due to stretching of its ligaments in response to displacement of fragments and, more rarely, by bone fragments and by its direct crushing between the pubic bones and the traumatizing object.

Injuries to the urinary bladder can be intra- and extraperitoneal. Intraperitoneal injuries, which arise predominantly in response to compression of a filled bladder, cause blood and urine to drain into the peritoneal cavity, eliciting peritoneal irritation and other peritoneal symptoms. The urinary bladder is thus "empty," though the urge to urinate may persist, and usually an insignificant quantity of urine mixed with blood or blood alone is discharged. Peritonitis develops later.

When extraperitoneal ruptures of the urinary bladder occur, its contents enter the tissue about the bladder, and then other areas of tissue in the pelvis and perineum. Urinary infiltration into tissue about the bladder is accompanied by pain and by dulling of the percussive tone. Dysuric disturbances are the same as those encountered with intraperitoneal rupture of the urinary bladder. Hematuria is also observed, though sometimes only towards the end of urination. Painful but unsuccessful urges to urinate may often arise.

But these symptoms may not be present in the first hours following trauma, since they may be overshadowed by other, more painful manifestations. Therefore when a patient with pelvic injury is being examined, a check of urination is mandatory. If just one of the symptoms listed above is revealed, a diagnosis of injury to the urinary bladder or urethra becomes probable. Drainage of urine through the wound or visual detection of injury to urinary organs in the wound are definite signs of injury to the urinary tracts.

Extraperitoneal injuries to the rectum may be suspected when blood is discharged from the anus, when palpation reveals blood in the rectum, and when chyle is discharged through the wound or gas escapes through the urethra (in the presence of a combined injury). Injuries to the lower divisions of the rectum may be revealed by palpation, from increasing painful swelling in the pararectal tissue, and by presence of a wound extending from the perineum to the rectum. A symptom complex typical of injury to the large intestine develops in the presence of intraperitoneal injuries.

Even a suspicion of injury to the urinary bladder, urethra, and rectum at the time of first physician's aid is enough to warrant implementation of all of the therapeutic and preventive measures possible at this stage.

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In the specialized aid stage, in which final medical aid is rendered, the diagnosis must be made more specific on the basis of special studies. When pelvic fractures are present the diagnosis is made more specific with the help of roentgenography. The anteroposterior exposure of the pelvis must include the entire pelvis. When necessary, the exposures are made with the use of special background grids. This helps to reveal the location and nature of injuries, and the extent and direction of displacement of fragments. Laboratory analyses are performed to establish the degree and nature of changes in blood and urine, to tentatively determine the amount of blood lost, and to clarify the presence and nature of accompanying injuries and complications.

The pseudoperitoneal syndrome accompanying pelvic fractures, elicited by a retroperitoneal hematoma, is relieved by an intrapelvic novocaine blockade; this would not cause a real peritoneal syndrome to disappear. Thus this procedure reduces the number of diagnostic laparotomies required.

If there is a suspicion of injury to the urinary bladder and the urethra, the main goal of diagnosis is to reveal whether or not these organs are damaged and, if injury had occurred, its type--penetrating or nonpenetrating. Next in the presence of a penetrating injury we reveal its location, and the location of urohematomas or congestions. This information is entirely necessary for the application of modern treatment methods. Some of this information can be acquired on the basis of the ease with which a catheter passes along the urethra, discharge of blood or urine through the catheter, and measurement of its quantity. For example intraperitoneal ruptures of the urinary bladder may be accompanied by discharge of an unusually large quantity of urine containing a great deal of protein (urine together with exudate from the peritoneal cavity).

The results of catheterization may indicate a need for deeper analysis.

The only way to quickly complete all or almost all diagnostic tasks is ascending urethro- and cystography.

In doubtful cases analysis begins with urethrography. Twenty milliliters of a 40 percent methiodal sodium solution (we can also use cardiotrast, diodone, gipak, sodium bromide, urotrast, and so on) are introduced through a catheter inserted into the urethra as far as the obstacle; a smaller quantity is used if a burning or spreading sensation arises. Then an X-ray is taken. Seepage of contrast solution into paraurethral tissue on the roentgenogram makes presence of a penetrating rupture of the urethra, its location, and the location of the urohematoma obvious.

If the symptoms of injury to the urethra are obvious and the results of contrast roentgenography are negative, then urethral injury is consequently limited to just the mucous membrane, and the urethral channel does not communicate with paraurethral tissues (a nonpenetrating injury is present).

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If rupture of the urinary bladder is suspected in the presence of obvious urethral integrity or was revealed by the method noted above, a catheter is inserted into the bladder, and then 250-300 ml (for an adult) contrast solution containing 150,000-200,000 AU penicillin is introduced through the catheter. Half the concentration of solution used to study the urethra can bem employed in this case. An X-ray exposure is made. A second exposure is made after evacuation of the urinary bladder. Accumulation of contrast solution in the peritoneal cavity attests to intraperitoneal rupture of the urinary bladder, and if contrast solution is discovered in tissue about the bladder, an extraperitoneal rupture is present.

The possibility that multiple ruptures of the urinary bladder, combination of intra- and extraperitoneal ruptures, and combined ruptures of the urinary bladder and urethra may occur should be kept in mind. In the presence of multiple ruptures, cystography reveals only some of them. Cystography is often found to be impossible in the presence of simultaneous rupture of the urethra, and it must be postponed to the time of surgery (after insertion of a catheter into the urinary bladder through the central division of the urethra). In the extreme case, air or oxygen can be used for cystography: Accumulation of gas above the pubic symphysis attests to an extraperitoneal rupture. But this method is less reliable, and it is not devoid of the possibility of dangerous complications.

When a rectal rupture is suspected, in addition to the analytical procedures already noted institutions of the hospital base could perform examinations with a rectal mirror, roentgenography (gas in the pararectal tissues and between muscles), and dynamic observation of the patient.

Therapy

First medical aid entails application of dressings, immobilization for travel, and administration of painkillers (promedol). The legs of a patient laid on a stretcher (a rigid one if possible) are partially bent. The thighs should not be forced together or apart: They should be placed in a position that is most comfortable to the victim. It would be desirable to bind, with moderate firmness, the patient's pelvis with a broad (20-30 cm) strip of fabric or a bandage.

In the stage of first physician's aid (the OPM) we implement measures to combat life-threatening disturbances and consequences of injury, to prevent development of infection, to prevent and treat shock, and to prepare the casualty for evacuation. These measures are implemented only to the extent possible in this stage, in correspondence with the qualifications of the physician, the availability of resources at the OPM, and the extent to which it is loaded.

Casualties with pelvic injuries requiring detention at the OPM for therapeutic and preventive measures are sent from the receiving and sorting department to functional subdivisions (dressing, surgical, antishock, terminal) while the rest are sent to the evacuation department.

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When open injuries are present antibiotics are injected intramuscularly, tetanus anatoxin and serum are administered, wound dressings are adjusted or applied, immobilizing resources are straightened or applied, medicinal and infusional therapy are provided as required by the indications, and external bleeding is stopped. In the event a casualty is discovered to be in shock, he is subjected to integrated antishock therapy (administration of narcotics, transfusion of blood and plasma substitutes, administration of cardiac agents, performance of novocaine blockades, inhalation of oxygen, warming of the patient, and so on) in accordance with the capabilities of the OPM. When arterial pressure is low (below 80 mm Hg) the antishock measures should begin with transfusional therapy, and after it is increased above 80 mm Hg a novocaine blockade should be performed.

It would be suitable to employ intrapelvic anesthesia using the Shkol'nikov-Selivanov method to prevent shock and prepare the casualty for lengthy evacuation, inasmuch as this method is simple and it does not require change of body position.

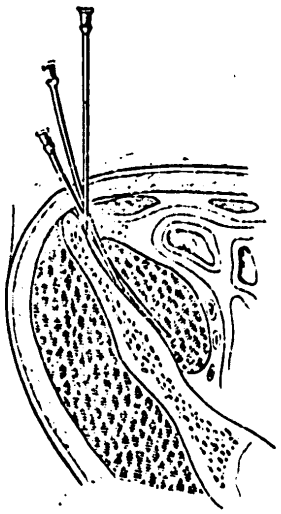

Figure 13. Introduction of Injection Needle for Intrapelvic Anesthesia

The anesthesia technique: The victim is placed on his back. The skin in the vicinity of the superior anterior spine on the injured side is wiped

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with tincture of iodine. The skin is anesthetized with a 0.25 percent novocaine solution injected 1 cm inward from the superior anterior spine; then a long thin needle (14-16 cm) is introduced along the inner surface of the ilium beneath the spine (Figure 13) through the soft tissues. Continuing to inject the novocaine solution, the physician tilts the needle and syringe outward; then the needle, which is now in the plane of the bone, is advanced, sliding effortlessly along the bone beneath the iliacus muscle. After this the 0.25 percent novocaine solution is injected at a dosage of 300-600 ml on one side or 250-300 ml on both sides (for an adult). The injected novocaine solution filters into the retroperitoneal tissue and pelvic tissue, drains into the places of pelvic bone fractures, and causes blockade of neural and vascular plexi.

To prevent novocaine intoxication 1-2 ml 5 percent ephedrine hydrochloride solution or 10 percent caffeine-sodium benzoate solution are added to the novocaine solution. In the event there is a threat of purulent infection in the pelvic region antibiotics are also added to the novocaine solution at doses from 100,000 to 200,000 AU.

Heating pads are applied to the abdomen to treat acute urine retention, when it is determined that overfilling of the urinary bladder is occurring and when there are no contraindications. If the victim's general condition permits and the hypothesized nature of injury is not an obstacle, an attempt can be made to change the victim's position. When these measures are ineffective or when injury to the urethral channel is obvious, the urinary bladder should be evacuated by means of capillary puncture.

Urinary bladder capillary puncture technique: Hair is shaved from skin overlying the pubis, after which it is wiped with tincture of iodine. The skin above the point of puncture is shifted with the finger, and a thin needle is introduced to a depth of 5-6 cm (for adults) 1.5-2 cm above the pubic symphysis and strictly rearward on the midline of the abdomen. If urine does not drain spontaneously, it is drawn out with a syringe. After the needle is removed the puncture point is sealed up.

Catheterization should be avoided at the OPM. If it is nevertheless found to be necessary for some reason it should be performed only with a rubber catheter, avoiding abrupt forces to surmount obstacles to the catheter's introduction. If catheterization is successful, at the end of the procedure 20-30 ml 1:5000 furacillin solution (or 0.5 percent protargol solution, 1 percent kollargol solution, 0.1 percent potassium permanganate solution) are introduced into the urinary bladder.

In the specialized aid stage casualties with pelvic unjuries, casualties in a state of shock, those exhibiting internal hemorrhaging, and casualties whose condition has worsened dramatically while en route are detained at the sorting and evacuation hospital or the main hospital. The rest of the casualties are sent to specialized traumatological or thoracoabdominal departments or hospitals.

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When combined traumas are present, casualties are hospitalized in the department responsible from treatment of the dominant injury.

Pelvic fractures not accompanied by injuries to internal organs are treated in a traumatological hospital. When simple marginal fractures and fractures not accompanied by disturbance of the pelvic girdle's continuity are present, with rare exceptions the treatment is conservative (anesthesia at the place of fracture, rest, a board beneath the mattress). The legs should be partially bent to permit uniform relaxation of muscles. The extent to which the legs are spread apart is determined in coordination with the location and degree of displacement of the fragments. It would be useful to apply local cold to the injured area for a short time (up to 1 hour). Limb massage, therapeutic physical culture (not eliciting pain), (sollyuks), and so on are prescribed beginning with the 3d-4th days. Surgical repositioning may be required in the event of fractures accompanied by considerable displacement of fragments (displacement of the superior anterior spine, the crest of the ilium, and so on) to restore the function of muscles attached to the fragments.

Suppositories containing anesthetic or opium and hot baths are prescribed for dislocation fractures of the coccyx. This group of patients undergoes hospital treatment until the capability for movement and self-care recovers (1-3 weeks).

Following elimination of shock and intrapelvic anesthesia, pelvic bone fractures accompanied by disturbance in the continuity of the pelvic girdle but not involving displacement of fragments are treated in the same way as fractures not involving disturbance of the pelvic girdle's continuity, but the length of therapy is governed by the time necessary for sufficiently firm knitting and by the functional significance of the damaged bones. In view of the great mechanical load placed on the posterior division of the pelvic girdle, fractures of the latter require hospital treatment for 8-12 weeks, while fractures of the anterior division require 6-8 weeks. It stands to reason that individual adjustments must be made in each case, on the basis of the anatomical and functional condition of the pelvis.

Pelvic fractures accompanied by displacement of fragments: Lateral displacements of parts of the pelvis are corrected by skeletal traction using the appropriate lower limb as the anchoring point. Prior to repositioning, it would be best to limit traction to that provided by slight (10-15°) flexure in the coxofemoral joint. The size of the weight (6-16 kg) depends on the amount of displacement and the degree of muscle development. After the displacement is corrected the size of the weight is decreased by about half. If the lateral part of the pelvis is rotated outward a pelvic bracing strap is used (Figure 14); its ends are rigidly secured above the victim (without crossing), or a traction system is fastened to them (a weight of up to 3 kg on each end). After the displacement is corrected the ends of the strap are crossed, which intensifies compression of the pelvis and helps to some extent to maintain the achieved adjustment.

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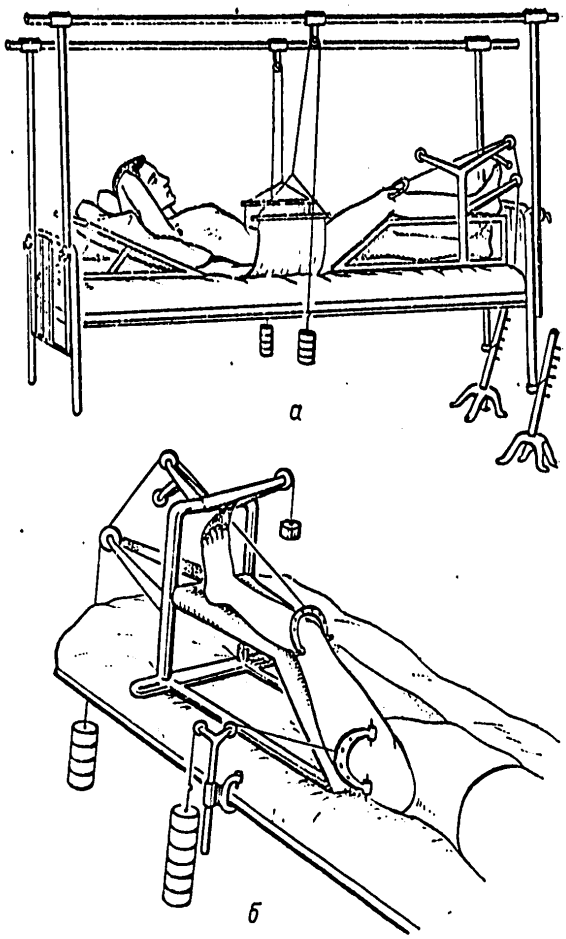

Figure 14. Traction for Pelvic Fractures: *а*--Fractures accompanied by displacement of the lateral division of the pelvis; *b*--central transacetabular fractures (subluxations and dislocations of the femur)

When a weight of more than 6 kg is used for repositioning, skewing of the pelvis must be prevented by placing the opposite limb under traction. The time of traction is 6-8 weeks. The time of hospital treatment is 10-12 weeks.

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Dislocation fractures and dislocations of the pelvis are accompanied by separation of bones in the pubic and sacroiliac joints. They are treated following the same rules applicable to vertical pelvic fractures accompanied by disturbance of the continuity of the pelvic girdle and displacement of lateral divisions of the pelvis.

When diastasis of the symphysis is extensive and proximal displacement of half of the pelvis does not occur, the victim is laid on his back with the legs partially flexed, and the pelvis is braced with a special hammock (a strap used to brace the pelvis). Four to eight weeks later a bandage bracing the pelvis is prescribed for 4-12 months. When it is impossible to stably correct diastasis of the symphysis, in certain cases surgical treatment would be required (symphysiorrhaphy).

When a dislocation or a dislocation fracture occurs, repositioning involves traction of the lower limb and bracing of the pelvis with a special strap. This treatment goes on for 8-12 weeks, after which the wearing of a bandage is prescribed for 4-12 months. Owing to mending of the bones, the continuity of the pelvic girdle is restored by the 3d month in the presence of dislocation fractures, and a bandage is no longer required or it is only needed for 1-2 months.

In some cases conservative treatment is found to be ineffective, the supporting function of the pelvis does not recover, and dislocation of half of the pelvis persistently recurs when traction is terminated. Surgery is indicated in these conditions (symphysiorrhaphy, iliosacral arthrodesis).

Transacetabular fractures not involving displacement are treated by anesthetizing the joint with 20-30 ml 2 percent novocaine solution. The injection needle is introduced forward of a point 2 cm out from the femoral vessels and below the inguinal ligament or along the anterior margin of the greater trochanter. Traction using a 2 kg weight (for an adult) is applied to a cuff secured to the shank. Active movements in the coxofemoral joint are prescribed after 3-4 days. Traction is terminated after 4 weeks, and the patient is permitted to walk on crutches without placing his weight on the leg on the injured side for 2-3 months.

When fractures involve displacement of fragments but not a dislocation, an attempt is made to achieve repositioning by skeletal traction. The direction of pull and the size of the weight are determined with a consideration for the degree and direction of displacement and the victim's muscle development. If the displacement is corrected, application of traction continues for 6-8 weeks; it is recommended that if a fracture had occurred, the patient should not place his weight on the leg for another 4 months.

When conservative resources fail to achieve repositioning, especially if the fragment is of considerable size, open repositioning should be performed, securing the fragment with a bone pin or by metallic osteosynthesis; this operation would best be performed in the 2d week following trauma.

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When dislocation of the femur occurs concurrently, we should first correct the dislocation under dependable anesthesia, after which the treatment goes on as with fractures coupled with displacement of fragments. When fractures involve disturbance of the continuity of the pelvic girdle, the pelvis should be secured (by hand or with a bandage) when setting the bone.

When fractures of the floor of the acetabulum are accompanied by medial displacement of the head of the femur, traction is applied in two directions--along the axis of the femoral neck using the great trochanter as the anchoring point, and along the axis of the femur using the epicondylic surface of the femur or the proximal metaphysis of the tibia as the anchoring point. Before the head is returned to its normal position the weight used for traction is 8 kg (for an adult with an average physical build) with the trochanter as the anchoring point, and 4 kg with the epicondylic surface of the femur as the anchoring point. The size of the weights is changed after the displacement is corrected: The pull on the trochanter is decreased to 4 kg, while that on the distal division of the femur is increased to 8 kg. If repositioning is successful, traction is continued for 6-8 weeks. Then physiotherapy and therapeutic physical culture are prescribed. Placing one's weight on the limb is prohibited until the end of the 6th month after trauma.

Open repositioning is indicated in cases of uncorrectable dislocation fractures and significant displacements; when open repositioning is impossible and the opposite joint is functioning well, arthrodesis is indicated.

Compound pelvic fractures are treated with a consideration for all of the rules of surgical wound treatment. Conservative treatment would be sufficient in the presence of nonpenetrating injuries to the bladder and urethra: Hematuria is treated with hemostatic agents (10 percent calcium chloride solution, gelatin, and so on), while a permanent catheter is inserted for 3-4 days when urination difficulties are present.

Surgery must be performed when penetrating ruptures are present, to include drainage of the urinary bladder, drainage of urohematomas, and restoration of the anatomical integrity of damaged organs. Surgical treatment is provided after the victim is stably out of a state of shock, after lost blood is replenished, and after preventive intrapelvic anesthesia is provided.

When intraperitoneal rupture of the urinary bladder occurs an inferior laparotomy is performed, and the wound on the urinary bladder is sutured shut; this is accompanied by meticulous peritonization of the seam and drying of the peritoneal cavity.

When the signs of peritonitis are present a microirrigator is introduced into the peritoneal cavity to permit repeat infusion of an antibiotic solution. The operation ends with creation of an epipubic urinary bladder fistula for temporary drainage of urine for 7-8 days. In very rare cases

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it would be sufficient to drain urine during the postoperative period with a permanent catheter (this requires full confidence that the injury is localized in one spot, an early operation, good condition of urinary bladder muscles, and a minor rupture).

In the event of extraperitoneal ruptures of the urinary bladder creation of an epipubic fistula and permanent catheterization are mandatory in the post-operative period, as is drainage of urohematomas or (later) leaked urine in the pelvis.

Sutures are applied to a urinary bladder wound if this does not involve significant dissection of the urinary bladder and the danger of disturbing its blood supply. When the possibility is present, individual wounds could be sutured from within the urinary bladder.

Surgical procedure: The patient is laid on his back with the pelvis slightly raised. Local infiltrational anesthesia is provided. An incision is made along the midline above the pubis 6-8 cm long, layer by layer until cellular tissue just above the bladder is reached. A urohematoma by the bladder could be lanced at this time. Wounds are dried and bleeding is carefully stopped. Cellular tissue about the bladder is separated and shifted proximal to the peritoneal fold. The wall of the urinary bladder can now be seen, distinguished by a unique intertwining of muscle fibers and the longitudinal arrangement of veins. Furacillin solution (1:5000) can be introduced through a catheter inserted into the urinary bladder, and injured areas of the bladder can be found quickly by leakage of the solution.

Two temporary sutures are applied to the urinary bladder 1-1.5 cm apart and as high up as possible; between them, first the muscular and then the mucous membrane is dissected. When necessary, the wall of the urinary bladder is felt with the finger from within through the resulting hole. A rubber drain tube is inserted into the hole. The hole in the bladder is constricted with double-row catgut sutures until the urinary bladder moves in response to movement of the drain tube. The urinary bladder is sutured with two catgut sutures to the aponeurosis. When urohematomas, infiltrated urine, or areas of urine congestion are present near the bladder, the cellular tissue above the bladder is drained by Kupriyanov's method. For this purpose dressing forceps are used to create a tunnel from the urinary bladder through the pelvic diaphragm to the perineum between the anus and the scrotum, the skin above the tip of the forceps is dissected, the drain tube is grasped, and its end is introduced into the cellular tissue about the bladder and, if necessary, through a separate incision on the peritoneal wall. In the event that urine has drained into cellular tissues in the lateral divisions of the pelvis, it is drained as well through separate incisions above and outward from the inguinal ligaments. The wound on the peritoneal wall is sutured layer by layer until the drain tube is reached, and the latter is secured (without piercing the tube) to the aponeurosis or the skin with one suture.

A strip of rubber is inserted into the retropubic space. Soft tissues about the surgical wound are repeatedly infiltrated with a 0.25 percent novocaine

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solution containing antibiotics. An aseptic dressing is applied. The drain tube is additionally secured to the skin by strips of adhesive tape or a gauze bandage (Figure 15).

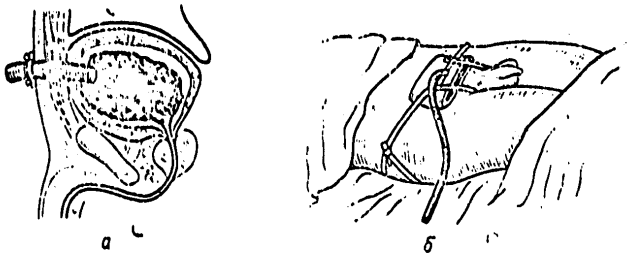

Figure 15. Epipubic Drainage of the Urinary Bladder (*a*) and Anchoring of the Drain Tube to the Peritoneum (*b*)

In the postoperative period the urinary bladder is flushed with furacillin solution 4 to 6 times a day. The time of draining usually does not exceed 10-14 days. To achieve more reliable constant evacuation of the urinary bladder a permanent rubber catheter is concurrently introduced by the usual means or, during surgery, through the inner aperture of the urethra.

Cellular tissue about the bladder can be drained by the Buyal'skiy-(Mak Varter) method. However, this would require additional surgery and significant separation of the victim's legs. With this method the tilt of the drain tube is less for a lying patient than with the Kupriyanov draining method.

Surgical procedure: An incision 4-6 cm long is made transverse to the axis of the thigh on its inner surface, 4-5 cm from the line of demarkation between the thigh and perineum, the adductor muscles are separated obtusely, and the obturator fascia and obturator muscle are dissected. A drain tube is introduced into the pelvic cavity through the medial division of the obturator foramen.

Such drainage is suitable when there are no indications for urinary bladder surgery.

In the event that victims do not arrive in large numbers and their immediate evacuation is necessary, the ideal drainage method in the presence of a penetrating rupture of the urethra is to apply a primary suture to the urethra around the catheter, and to drain paraurethral hematomas and cellular

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tissues of the pelvis. The urethral suture could also be applied later, after 2-4 days, if purulent inflammation has not developed by this time.

Surgical procedure:

Intrapelvic anesthesia is provided. The patient is set up in the position for perineal surgery. The scrotum is shifted forward. The skin and superficial fascia are dissected with an arched incision having its convexity forward and its ends in the vicinity of the ischial tuberosities. This is usually enough to evacuate a perineal urohematoma and expose the rear wall or the urethra. If this does not occur, the perineal tissues are obtusely delaminated. When ruptures are present in the posterior division of the urethra, the pelvic diaphragm is usually torn as well. To facilitate orientation, a catheter is introduced into the urethra beforehand. Its end often protrudes through the wound. There is no difficulty in finding the distal division of the urethra. It is also easy to find the end of the central division of the urethra when an incomplete rupture (not affecting the entire circumference of the urethra) is present. When a complete rupture is present it may be difficult to find the end of the urethra's central division. It could be found with reliance upon a knowledge of the topography of this division, by drainage of urine in response to pressure upon the urinary bladder and, in the extreme case, by the place of emergence of a catheter introduced through an epipubic wound of the urinary bladder.

After the central division of the urethra is found, its ends are joined together on the anterior wall, and then the catheter is moved through the central division into the urinary bladder, and another three sutures are applied, this time to the catheter (two lateral and one posterior), encompassing not only the wall of the urethra but also the paraurethral tissue. Thus we achieve anatomical restoration of the urethra. Then an epicystotomy is made. The perineal wound is constricted, and a rubber strip is inserted through it for its entire depth to permit drainage. The catheter should be firmly anchored with a suture clamp on the peritoneum (when an epicystotomy is made) or with adhesive strips applied to the glans penis ("basket" bandage).

When a primary suture is applied to the urethra around the catheter, stable healing occurs in 2-3 weeks without stricture, and the need for subsequent restorative surgery, which is not always effective, is precluded. Healing occurs 4-5 days later with postponed urethrography.

If for some reason a suture cannot be applied to the urethra (extensive tissue damage, a purulent inflammatory process, the victim's serious overall condition, and so on), when an epicystotomy and lancing of a urohematoma are necessary, an attempt should be made to introduce a catheter or a rubber tube (8 mm diameter) from within the urinary bladder, and the ends are joined together on the outside. If diastasis of the urethra occurs, recovery takes at least 6-8 weeks, and during this time the catheter or tube must remain in the urethra to prevent stricture of the urinary duct (resulting from scarring caused by the urethra's collapse).

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In cases where surgery is limited to making an epicystotomy and draining a perineal urohematoma, restorative surgery would be required later to correct stricture or obliteration of the injured portion of the urethra, or to eliminate urinary fistulas.

To prevent complications in the area of urethral sutures about the catheter, the urinary bladder should be flushed with furacillin solution (1:5000) four to six times, and an antibiotic solution should be introduced through the outer opening of the urethra between the catheter and the urethra's mucous membrane.

Injuries to the rectum are encountered relatively rarely in the presence of simple pelvic fractures; when they do occur, they are caused both by ruptures in the vicinity of the anus due to stretching of tissues and by bone fragments. Injury could also occur when the victim falls in squatting position.

When extraperitoneal injuries are minor, excluding those of the anal region, conservative treatment of rectal injuries carries a high risk due to the danger of development of fecal phlegmons in the pelvis. Intraperitoneal injuries are treated in accordance with the same rules applicable to other divisions of the large intestine. When penetrating wounds are present in the extraperitoneal division the pararectal tissues must be extensively dissected by the most convenient means, considering the location of the wound; soiled cellular tissue should be excised, hematomas should be removed, wounds on the intestine should be sutured, and the latter should be drained with a drain tube inserted through loosely laid tampons. Before the tampons are introduced, 1,000,000-2,000,000 AU of antibiotics are placed in the wound and the soft tissues surrounding the wound are infiltrated with antibiotic solution. The outer sphincter of the rectum is stretched apart to preclude an increase in intraintestinal pressure. A temporary unnatural anus is created on the sigmoid colon early during initial surgical treatment (on the basis of the primary indications) only when there is extensive damage to the rectum; this procedure is also performed later in the event that serious complications develop (on the basis of secondary indications). Opium tincture and a diet with a minimum cellulose content (first 5-6 days) and intense antibacterial therapy are prescribed in the postoperative period.

The therapeutic principles followed with open injuries are the same, except that careful surgical treatment of wounds would be required.

The sequence of surgical measures implemented in the presence of combined injuries in the same location must account for the direct danger they offer to the victim's life. Breathing and circulatory disturbances are eliminated first.

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CHAPTER 5

SPINAL AND SPINAL CORD INJURIES

Spinal and spinal cord injuries made up 1.28 percent of all casualties in the Great Patriotic War (I. S. Babchin, 1954). It should be assumed that the true number of these injuries was probably higher in combat operations, since some of the wounded personnel with severe injuries to the upper cervical division as well as with combined gunshot wounds of the thoracic and peritoneal cavities died on the battlefield or at the forward medical aid points (A. V. Bondarchuk, D. G. Gol'dberg, 1954).

Closed spinal and spinal cord injuries were encountered much more rarely than gunshot wounds in the field in the Great Patriotic War, making up 0.2 percent of all combat injuries of the spine.

It is believed that in a modern war closed spinal and spinal cord injuries would dominate over open injuries. Injuries to the spine and spinal cord may make up 6-8 percent of all battle traumas.

Classification of Spinal and Spinal Cord Injuries

We distinguish between open spinal and spinal cord injuries, typified by disturbance of the integrity of the skin, and closed injuries, in the presence of which the integrity of the skin is not disturbed.

Open spinal injuries, which are accompanied by disturbance of the integrity of the wall of the spinal canal, are penetrating injuries. Nonpenetrating injuries are open injuries in the presence of which the integrity of spinal canal walls is not disturbed.

All spinal and spinal cord injuries are divided into injuries of:
a) The cervical division of the spine and spinal cord; b) the thoracic division of the spine and spinal cord; 3) the lumbosacral division of the spine and spinal cord, and of the cauda equina (V. M. Ugryumov, 1961).

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It is extremely important to reveal the degree of disturbance of spinal conduction in this case. Victims must be subdivided into three groups depending on this factor: 1) With total disruption of conduction in the spinal cord or the roots of the cauda equina; 2) with partial disturbance of conduction in the spinal cord or roots of the cauda equina; 3) without disruption of conduction in the spinal cord or roots of the cauda equina.

We would also have to isolate combined injuries that are the most serious in relation to clinical course and outcomes: a) Injuries to the spine and spinal cord combined with injuries to the skull and brain; b) spine and spinal cord injuries combined with injuries to internal organs of the thoracic and peritoneal cavities, as well as with injuries to organs of the lesser pelvis.

The classification of spinal and spinal cord injuries must account for stability and instability, which have a great influence on the nature of therapy.

Spinal injuries coupled with rupture of back ligaments are unstable. These injuries have a flexural-rotational mechanism. If in the presence of this traumatic mechanism force causes rupture of an intervertebral joint capsule or separation of articular processes, a dislocation results.

Combined fractures and dislocations are among the unstable injuries, since subsequent movements, more significant than those occurring at the time of trauma and having a more profound influence on the spinal cord, membranes, and roots, may occur in their presence. The opinion exists that unstable fractures should include all serious wedge-type fractures of vertebral bodies, inasmuch as they are in fact dislocation fractures. The group of stable fractures includes most wedge-type compressions of vertebral bodies and all fractures of vertebral arches proximal to the fourth lumbar vertebra. One of the clinical criteria of fracture instability is separation of the tips of the spinous processes. The final decision as to whether it is a stable or unstable fracture is made on the basis of roentgenological analysis.

V. M. Ugryumov (1961) proposed the most improved classification of spinal cord injuries specifically. It can be presented in the following form, with additions pertaining to disturbances of spinal cord circulation:

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Concussion
Contusion
Crushing coupled with partial disturbance of the anatomical integrity of the spinal cord, or its breakage
Circulatory disturbance:
a) hematomyelia
b) epidural, subdural, and subarachnoid hemorrhaging
c) anterior spinal artery syndrome
d) softening of the spinal cord owing to functional circulatory disturbances

} May be accompanied by compression of the spinal cord

Gunshot spinal and spinal cord injuries are divided into five types in Kosinskaya's classification (1945) (Figure 16).

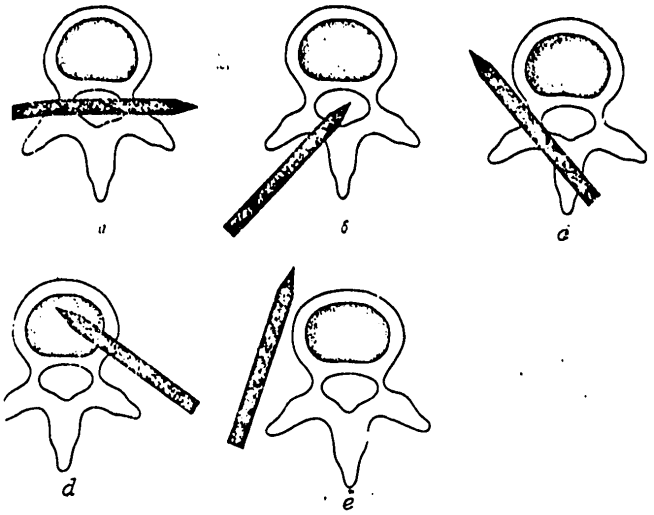

Figure 16. Classification of Gunshot Wounds of the Spine and Spinal Cord (from N. S. Kosinskaya): *a*--through wound; *b*--blind wound; *c*--tangential wound; *d*--nonpenetrating wound; *e*--paravertebral wound

Among closed spinal injuries, we distinguish contusions, fractures, dislocations, dislocation fractures or fractures coupled with displacement, distentions and ruptures of ligament systems, abruption of

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the laminae, and injury to intervertebral disks coupled with hernial protrusion of the disk from the body of the vertebra, or into the spinal canal itself.

Clinical Pattern of Spinal and Spinal Cord Injuries

The general condition of casualties with spinal and spinal cord injuries depends on the severity and location of spinal cord injury, and on the nature of accompanying injuries to internal organs and the brain.

In the acute period many casualties are sluggish, apart, and pale. Impairment of consciousness that may be preceded by a period of arousal and euphoria frequently accompanies injuries to the cervical division of the spine. In addition to pathological effects on the medulla oblongata resulting from ascending edema (swelling), disturbances in circulation in the vertebrobasilar system have recently been credited with great significance in the pathogenesis of impaired consciousness. Breathing disturbances are observed with injuries to the cervical division of the spine.

Auxiliary musculature begins to participate in the breathing act, and rales and dryness of the mucous membrane of the mouth cavity appear. The lines of the face are sharpened, and it is often hyperemic. It is difficult to cough up sputum and to swallow, especially in the presence of high injuries to the cervical vertebrae. Body temperature remains high for a long time in the presence of such injuries as a rule. Hypertension, observed more often with injuries to upper thoracic vertebrae, is not always associated with severe injuries to internal organs. In I. Ya. Razdol'skiy's opinion (1952) there is a close dependence between hemodynamic disturbances and injuries to the spinal cord itself.

Body temperature is observed to decline in the presence of injuries to upper thoracic vertebrae. Motor disturbances accompanying severe injuries to the spine and spinal cord exhibit acute development. Paralysis develops in the corresponding limbs, usually symmetrical, in most victims following trauma.

When injuries to the spine and spinal cord are less severe, motor disturbances do not always attain the paralysis level. Development of various sorts of pareses, extremely rarely limited to just one half of the body, is possible. Constant deepening of motor disturbances that had arisen at the time of spinal cord injury is observed when victims are transported incorrectly; this can lead to displacement of fragments of vertebral bones and secondary trauma of the spinal cord in the presence of growth in circulatory disturbances within the spinal cord, and in the presence of the development of limited epidural and subdural hemorrhaging and edema--brain swelling. Muscle tone in paralyzed limbs is low immediately following trauma. As a rule the tendon, periosteal, and skin reflexes disappear. Concussions and mild contusions of the spinal cord are an exception; maintenance of reflex activity coupled with a certain exaltation of reflexes is possible in the acute period of trauma in their presence.

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Recovery of movements is possible in the presence of partial injuries and compressions of the spinal cord after spinal shock phenomena disappear. As far as tone and reflexes are concerned, the sluggish tone of musculature accompanying high spinal cord injuries is gradually replaced by an increase in tone on the background of heightened tendon and periosteal reflexes.

Development of the anterior spinal artery syndrome is possible in the presence of spinal and spinal cord injuries; this is the reason for the severity of the accompanying neurological disturbances, which have certain unique features: Acute development of pareses or paralyses coupled with higher or lower superficial sensitivity and maintenance of profound sensitivity, without disturbance of the conduction of liquor channels. Another important symptom of disturbed circulation in the spinal cord is an incorrespondence between the extent of neurological disturbances and the extent of injury to the spine and spinal cord.

Sensory disturbances occurring in the acute period of trauma are of equal extent in both halves of the body, and they mainly affect conduction. When the anterior spinal artery is crushed, segmental impairments can sometimes be detected at the corresponding level, while functions of the vertebral column posterior to the point of compression remain normal. Recovery of sensitivity in the acute period of trauma is possible in the presence of spinal cord concussions and incomplete transverse injuries.

Injuries to the spinal cord are accompanied by disturbed sensitivity in the spine one to two segments and more above the level of injury. The pathogenesis of this inconsistency is based on disturbances in spinal circulation, especially in the system of the anterior spinal artery.

Disturbance of Urination

The nature, frequency, and stability of urination disturbances depend on the level and degree of spinal cord injury as well as on the time since trauma.

We distinguish between two types of urination disturbances: 1) Conductive, in which the main focus of injury is above the spinal centers regulating urination; 2) the disturbance observed in the presence of injury to spinal centers regulating urination.

In the presence of the first type of urination disturbance we first witness total urine retention. The higher the location of the injury to the spinal cord, the faster automatic evacuation of the urinary bladder and, subsequently, its reflex evacuation recover. When injury occurs to the second, third, and fourth lumbar segments, which contain the sympathetic center regulating the inner sphincter of the urinary bladder, urine retention is subsequently superceded by persistent involuntary urination (I. Ya. Razdol'skiy, 1952).

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When injury occurs to the third or fourth sacral segments paradoxical involuntary urination arises owing to developing paralysis of the detrusor urinae muscle, with sphincter tone persisting.

Principles of Therapy

Searching for and removing victims from areas of mass destruction, it is important to consider that persons with injuries to cervical vertebrae may be unconscious. Extrication of victims from various structural rubble must be done cautiously, without pulling arms, legs, or clothing.

First Medical Aid

First medical aid entails application of aseptic dressings to existing wounds and creation of conditions favorable to breathing. When injuries to the thoracic or lumbar vertebrae are present, victims are placed on a rigid stretcher (or panel) on their stomach, and if the cervical division of the spine is injured they are placed on their back. The head and the cervical vertebrae are immobilized by Cramer splints or a Schanz cotton gauze collar.

The victim must be moved to the stretcher by two orderlies abdomen downward in the event of injury to thoracic and lumbar vertebrae, and back downward in the event of injuries to cervical vertebrae. Victims on stretchers must be covered well, especially in winter. Their transportation by hand or using clothing or tarpaulins as stretchers is impermissible, since in this case secondary displacements of injured vertebrae are possible, which can dramatically worsen the victim's condition. Cardiac preparations, respiratory stimulants, and analgesics are administered. In the case of breathing arrest, mouth-to-mouth or mouth-to-nose artificial respiration should be performed.

First physician's aid is rendered on the basis of emergency indications to:

1) Casualties with injury to the cervical division of the spine and spinal cord in the presence of pronounced breathing disturbances. Treatment includes tracheostomy, active dehydration (mannitol, urea), aspiration of mucus from the bronchial tree, inhalation of humidified oxygen, control of hyperthermia and mechanical respiration;

2) casualties with injury to the spine and spinal cord with manifestations of shock. Integrated therapy for traumatic shock is performed;

3) casualties with injury to the spine and spinal cord combined with injury to the skull and brain coupled with severe cerebral phenomena and with injury to organs of the thoracic and peritoneal cavities as well as organs of the lesser pelvis.

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The volume and nature of the aid rendered depend on the severity of the pathology of a given organ and the significance of this pathology to the disease pattern.

Casualties with injuries to the spine and spinal cord must be evacuated directly to specialized hospitals, in special transportation if possible.

The medical indications define the evacuation priority. Casualties with injuries to the cervical division of the spine and spinal cord not exhibiting respiratory disturbances or exhibiting the initial degree of respiratory disturbance--rapid breathing alone--are evacuated on first priority. An attempt should be made to evacuate such persons in the first 12-24 hours after trauma, prior to development of intestinal paresis, which significantly worsens respiration and cardiac activity. This group is followed by persons with open penetrating injuries to the spine and spinal cord as well as casualties with unstable injuries to the spine and spinal cord.

Casualties with stable fractures of the spine and spinal cord, with partial disturbance of conduction in the spinal cord, and with injury to roots of the cauda equina are evacuated on second priority.

Casualties with injuries to the spine and spinal cord are evacuated on the stretchers they had occupied at the OPM. It is undesirable to move them to other stretchers when special circumstances do not require this.

Prior to evacuation, casualties are subjected to catheterization of the urinary bladder, leaving the catheter in place. Casualties must be well covered. A hypodermic injection of promedol should be given, and cardiac agents should be administered when the indications for doing so are present.

Specialized Aid

The fundamental principle of rendering aid to casualties with traumas of the central nervous system in a modern war would be simultaneous exhaustive therapy in specialized neurosurgical institutions. Neurosurgical hospitals of the hospital base must be ready for simultaneous admission of a large number of casualties with injuries to the spine and spinal cord.

A neurosurgeon and a neuropathologist examine casualties in the receiving and sorting department. Victims with unstable spinal fractures, those exhibiting a pattern of growing neurological symptoms of spinal cord injury, and persons with injury to the cervical division of the spine and spinal cord are subject to roentgenological examination and liquor dynamics tests on first priority. Persons with stable spinal fractures are subjected to such examination on second priority.

The indications for surgery are:

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1. Growth in the neurological symptoms of injury to the spinal cord during observation of patients in the first hours and days following trauma.

2. Disturbance of conduction in subarachnoid spaces in the presence of complete or partial disturbance of conduction in the spinal cord.

3. Irritation and compression of the roots of the cauda equina caused by bone fragments and slippage of an intervertebral disk.

Surgery performed in the presence of spinal and spinal cord injuries should f[illegible]see: Recovery of normal mutual relationships between the spine, the spinal cord, the membranes, and the roots; removal of bone fragments, pieces of ligaments, and blood clots that had penetrated into the lumen of the vertebral canal; recovery of liquor drainage through the subarachnoid space of the spinal cord; normalization of circulation in the spinal cord, or reduction of vascular disturbances; reduction of irritation of the conducting elements of the spinal cord, and its decompression; stabilization and, as the indications require, fixation of the spine.

The neurosurgical tactics applicable to fractures of cervical vertebrae have their unique features. When dislocations and combined fracture-dislocations are not complicated by disturbances in liquor dynamics and fractures of vertebral arches and articular processes, treatment follows the method of skeletal traction using the parietal eminences as the anchoring points. Surgery is indicated in the presence of dislocations and combined fractures-dislocations proceeding with distinct disturbances in liquor dynamics and the corresponding neurological disturbances.

All casualties are given preventive treatment for bedsores, the main goal of which is to improve circulation in places of the body experiencing maximum pressure, and to reduce this pressure. When bedsores are already present, the therapeutic tactics are different. In the early stages we employ conservative therapy predominantly--warm procedures (paraffin, ultraviolet radiation), evacuation of blisters, aseptic dressings.

When treating bedsores in the necrotic stage it is important to consider the victim's general condition, the location and extent of the bedsore, its relationship to bone formations, the species composition and biological characteristics of bacteria, and the reactivity of the wounds.

Bedsores in the heel area, on the shanks, in the vicinity of the crests of the iliac bones, and the rear surface of the foot, elbows, and torso are treated conservatively, in combination with removal of necrotic tissues.

Local use of antibiotics to which bacteria are sensitive and employment of physiotherapeutic procedures and biogenic stimulants accelerate healing of bedsores in these areas.

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Bedsores in the vicinity of the sacrum, ischial tuberosities, and the trochanters require surgery. Preparation of patients for surgery includes--in addition to a general strengthening diet rich in proteins and vitamins--determination of the species composition of the microbial association in the bedsore and performance of antibacterial therapy (local and general). Wound reactivity has great significance to the choice of optimum operating time. When wound reactivity is weak, which can be revealed by taking smears of wound exudate, and when there are large numbers of pathogenic bacteria, the success of bedsore surgery is extremely doubtful.

Presence of numerous fibroblasts in the wound exudate and a small number of weakly pathogenic bacteria increases the chances of a favorable outcome to surgery.

All surgery undertaken for reason of bedsores must foresee creation of a constant and dependable covering in its area, after removal of nonviable tissues, poorly vascularized scars, and inflamed bone formations.

There are several types of operations performed on bedsores and trophic ulcers. Freehand plastic surgery using the Davis, Thiersch, and Yanovich-Chainskiy methods is employed with superficial bedsores. The success of surgery depends on a number of conditions--absence of scar tissue and pathogenic flora from the floor of the wound, and presence of good granulations filling the wound. There are limited indications for employing the bedsore closing method involving mobilization of the bedsore's margins followed by suturing because it is complicated by frequent recurrence of bedsores in view of poor vascularization of the sutured margins, and the great tension they experience.

Transplantation of dermal panniculi replacing the entire thickness of the bedsore ensures a firm covering for the bedsore, which is the advantage of this method. But a panniculus does not always attach in view of poor vascularization of the substrate upon which it is laid. Transplantation of pedicular panniculi is the most dependable. The panniculi are taken from nearby portions of the skin, and they consist of not only all dermal layers but also underlying connective tissue.

Recovery of the ability to urinate in the acute and subacute periods of spinal and spinal cord trauma goes a long way in making the course and outcome of traumatic spinal cord disease favorable.

Treatment of a "urogenic urinary bladder" in the hospital base of the out-of-town zone must be based on cystometric and sphincterometric data, cystourethrography, and electromyography. First of all we would have to resolve the question as to the method for draining urine in the first months following trauma, before recovery of reflex control of urination.

Periodic catheterization of the urinary bladder, even with the most meticulous observance of aseptic conditions, leads to infection of urinary ducts.

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Use of a permanent catheter leads to infection of the urinary tract more rarely. A permanent catheter is left in the urinary bladder for 3-4 days. The space of the urinary bladder is rinsed with antiseptic solutions daily. The choice method 1-3 months after trauma, prior to recovery of reflex-controlled evacuation of the urinary bladder, is employment of a two-way flow system to permit constant irrigation of the urinary bladder with antiseptic and maintenance of pressure within the bladder at the optimum level.

The urinary bladder is rinsed with warm solutions of rivanol, furacillin, and boric acid. Every 3-4 days the two-way flow system is turned off, the catheter is removed from the urinary bladder, and 8-12 hours later the permanent catheter is put back in place and the two-way flow system is turned back on.

Transrectal electrostimulation of the urinary bladder is a means for accelerating recovery of reflex-controlled urination(N. Ye. Savchenko, V. A. Makhort, 1970; V. A. Toritsyn, 1971); another means is electrostimulation of the urinary bladder by a stimulating device implanted within it (A. A. Vishnevskiy, A. V. Livshits, 1973).

In a number of observations electrostimulation of the urinary bladder (direct or indirect) has led to spastic contraction of sphincters coupled with worsening of urination. Pudendal nerves are subjected to a novocaine blockade in order to weaken sphincter tone.

Cyclic medicinal prevention of urinary infection is prescribed for many months following trauma. Antibiotic therapy is provided with a consideration for urinary microflora and its sensitivity to antibiotics; antiseptic treatment is provided as well.

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CHAPTER 6

UPPER AND LOWER LIMB BONE FRACTURES

Upper Limb Bone Fractures

Bone Fractures of the Pectoral Girdle

Fractures of the scapula occur in response to its contusion, falling on the back, and other direct traumas. The clinical pattern depends on the location of the fracture.

Symptoms: Limited swelling, painfulness of movements in the shoulder joint, and crepitation in response to pressure on the acromial process are noted in the presence of fracture of the acromial process. Fractures of the acromial end of the scapula are often incorrectly diagnosed as fractures of the outer end of the clavicle or as dislocation of its acromial end.

The clinical pattern of fracture of the joint socket recalls fracture of the head and neck of the humerus or its dislocation.

Fracture of the neck of the scapula produces typical symptoms, since the peripheral fragment shifts downward and inward, often concurrently traumatizing the axillary nerve, which leads to paresis of the deltoid muscle.

Fracture of the body, the superior, and the inferior angle of the scapula as well as its spine is accompanied by swelling, hemorrhaging, and pain in the area corresponding to the fracture.

First medical aid and treatment: A cotton pad is inserted into the armpit, and the arm, bent at a right angle at the elbow joint, is secured to the chest with a Desault bandage, or it is slung in a triangular bandage. The victim should be sent to the OPM, from which he is evacuated in seated position to the hospital base for specialized traumatological aid.

Roentgenograms have great significance to diagnosis. Fractures of the acromial process, the neck, and the joint socket involving displacement of fragments are treated with an abductive arm splint secured 10° back from the frontal

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plane. The splint is worn for a month. Therapeutic physical exercises are performed beginning with the first days; movement of the shoulder joint is started on the 15th-20th days. In the presence of all other types of fractures of the scapula a Desault bandage is worn for 5-7 days or a triangular bandage is employed, and therapeutic gymnastics are performed.

Fractures of the clavicle usually occur in the middle third on the border between the outer and middle thirds of the clavicle in its most bent and thinnest part. Fractures of the clavicle in adults usually involve displacement. The central fragment is usually located above and to the rear, while the peripheral fragment shifts downward, forward, and inward.

Although injury to the neurovascular tract and the cervical pleura is possible in the presence of simple fractures of the clavicle, it is rare. Children exhibit predominantly subperiostal fractures: The clavicle of children experiences green-stick fracture.

Symptoms: Swelling, hemorrhaging, and deformation are visible in the fracture area. Palpation of and pressure on the fracture area are painful. Movements in the shoulder joint cause pain in the area of clavicle fracture; abnormal mobility and crepitation are sometimes detected in this case.

Examination of the victim should conclude with determination of the pulse in the radial artery and determination of skin sensitivity and finger movements. Depending on age, fragments knit in 2-5 weeks. As a rule, knitting of the fragments, even if they are somewhat displaced, does not produce noticeable functional disturbances.

First medical aid and treatment: A Desault bandage or a triangular bandage is applied. The victim should be sent to the OPM, from which he is evacuated in seated position to the hospital base for specialized traumatological aid. In the specialized treatment stage, following clinical examination, an X-ray is taken to provide a precise idea of the nature of the fracture and fragment displacement. In order that the fragment could be set, the upper arm must be raised and rotated backward and outward. A figure-of-8 bandage (Figure 17 *a, b, c*) is used on children with fractures of the clavicle without displacement or with minor displacement. After local anesthesia (20 ml 1-2 percent novocaine solution), cotton gauze quilted pads are placed over the anterior surfaces of both shoulder joints and in the axillas. Several rolls of bandage are used to make a figure-of-8 bandage. The bandage goes in front of the shoulder joints and beneath the armpits, and it crosses between the scapulae. During bandaging, the bandage is tugged upward and back. Care should be taken not to crush the neurovascular tract with the bandage; this is checked by feeling the pulse in the radial artery. The ends of the bandage are sewn together so that it would not weaken.

Special splints or a Cramer splint, bent into an oval (Figure 18), are also used to treat fractures of the clavicle. In order that the shoulder would

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be drawn backward the surface of the splint resting against the axilla must be tilted from front to back. The splint keeps the peripheral fragment elevated and forces it backward.

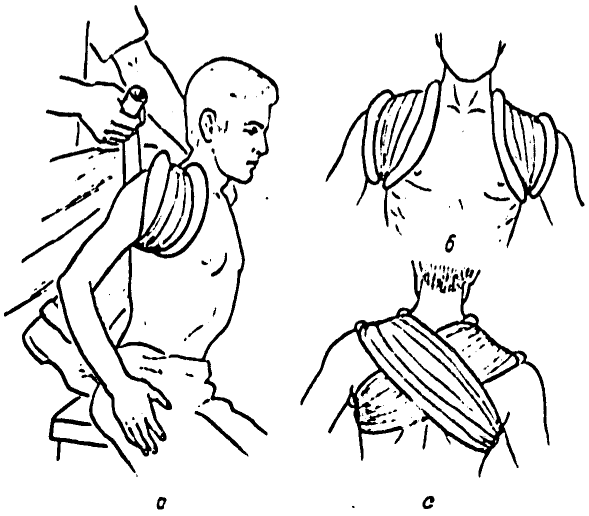

Figure 17. Repositioning of a Fractured Clavicle, Application of a Figure-of-8 Bandage (*a*); Front View (*b*); Back View (*c*)

When fractures do not involve displacement the bandage or splint is removed in 2-3 weeks, while if displacement has occurred the time is 3-4 weeks. In older children, fragments knit within 15-20 days and do not require subsequent treatment.

Surgical treatment of fresh simple fractures of the clavicle is indicated when the neurovascular tract is injured or crushed, and when there is a danger that an attempt at repositioning fragments may cause perforation of the skin or injury to the neurovascular plexus. Surgery is also indicated if, despite an attempt at repositioning fragments, they remain considerably displaced, and if their knitting in this position would result in significant deformation. If there are no emergency indications, the surgery should be performed on the 2d-3d days after trauma. The best anchoring of fragments is achieved with intraosteal insertion of a thick stainless steel spoke, a Bogdanov nail, or special plates.

Surgery is performed on children with fractures of the clavicle in exceptional cases, when there is the danger of injury to the neurovascular tract. Displacement of fragments does not by itself serve as an indication for surgery.

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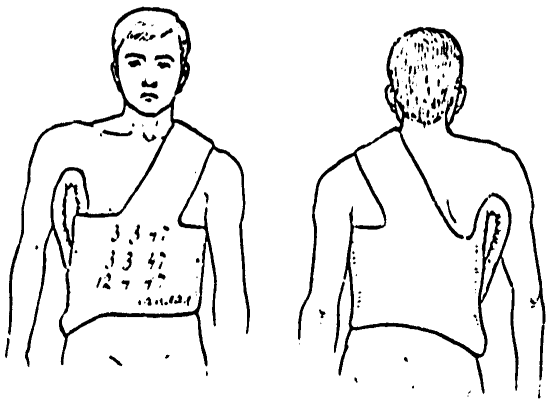

Figure 18. Patient Wearing Bandaged Splint for a Fractured Clavicle and Scapula

Fractures of the Humerus and Associated Joints

Fractures of the upper end of the humerus occur in response to a blow in the vicinity of the head of the humerus, and in response to a fall on the elbow and wrist. The following are observed in this area: 1) Fractures of the head and anatomical neck of the humerus; 2) fractures of the surgical neck and epiphysiolysis of the head in children; 3) isolated fractures and separations of the greater and lesser tuberosities of the humerus.

Fractures of the surgical neck of the humerus are encountered most often.

Symptoms: The symptoms for all types of fractures of the upper end of the humerus are similar. Greater or lesser swelling, hemorrhaging, and pain are noted around the shoulder joint. The outlines of the shoulder joint persist. Palpation of and pressure applied to the upper end of the humerus cause pain, while light tapping of the elbow in the direction of the axis of the humerus produces pain in the upper end of the humerus. Sharp pains are sensed in response to movement in the shoulder joint.

Fractures of the upper end of the humerus can sometimes be complicated by injury to the subclavian nerve and its branches innervating the deltoid muscle. The upper end of the lower fragment may crush and sometimes damage the neurovascular bundle in the axilla. Pressure on the neurovascular bundle causes edema, venous congestion, disturbance of sensitivity, paresis, and paralysis of upper limbs. When the surgical neck of the humerus is fractured, in some cases an angle open inward and rearward forms between the bone fragments (abductive fracture), while in others both fragments form an

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angle open outward and rearward (adductive fracture). In the presence of both types of fractures the proximal end of the humerus is often impacted into the head of the humerus to a greater or a lesser degree. Angular displacement of fragments lying between central and peripheral fragments of adductive and abductive fractures of the surgical neck of the humerus can be insignificant in some cases and considerable in others.

In addition to impacted fractures of the neck of the humerus not involving displacement and impacted and nonimpacted adductive and abductive fractures, we can encounter fractures of the surgical neck coupled with dislocation of the detached head of the humerus.

Circumepiphyseal cracks and fractures as well as epiphysiolysis are observed in children in the vicinity of the surgical neck of the humerus. A crack accompanying an epiphysiolysis often extends into the metaphysis. Detachment along the epiphyseal line may be accompanied by injury to temporary cartilage, elicit premature ossification, and serve as the cause of retarded limb growth.

Isolated fractures and detachments of the greater and lesser tuberosities of the humerus are often observed together with both injury accompanying fractures of the neck of the humerus and shoulder dislocation. When shoulder dislocations occur the greater tuberosity breaks owing to its striking of the margin of the joint socket, or its detachment by reflex contraction of muscles attached to it.

First medical aid and treatment: A victim with trauma of the shoulder joint is sent to the OPM, where an immobilizing bandage is applied together with a Cramer splint (Figure 19), or a Desault bandage is put on. When pains are intense, 1 ml 1-2 percent promedol or omnopon solution or 21 ml 1-2 percent novocaine solution should be injected subcutaneously at the place of fracture. Antibiotics and tetanus serum must be administered concurrently in the presence of compound fractures. All measures implemented are noted on the appropriate medical card of the victim. He is evacuated in seated position to the hospital base, where specialized traumatological aid is rendered.

After clinical examination, X-rays are mandatorily taken to permit a more definite diagnosis. In all cases of compound fractures the wound is subjected to initial surgical treatment.

When fractures of the head and neck of the humerus occur, 20 ml 1-2 percent novocaine solution are injected in the area of the fracture to relieve pain and reduce muscle tension. The arm is suspended in a sling when cracks are present and when there are impacted fractures of the surgical neck without displacement or with slight angular displacement. A thick cotton pad, to which two wide straps are sewn, is first fitted in the axilla. The straps are tied together over the healthy forearm. Therapeutic physical culture is prescribed beginning with the 2d day.

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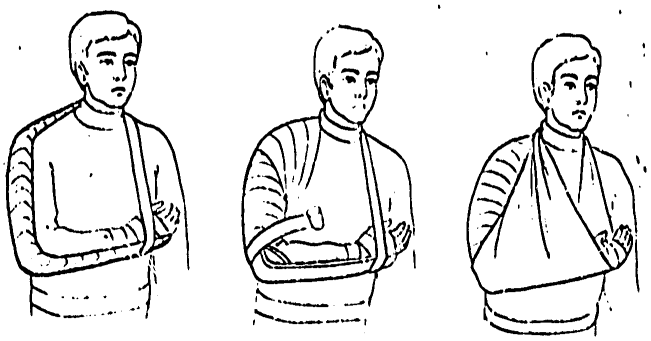

Figure 19. Immobilization of Fractured Shoulder Joint and Humerus for Travel

Among young and middle-aged people as well as older children, the angle of the fragments resulting from the adductive fractures of the surgical neck involving angular displacement is open inward. In such cases an abductive splint is used together with external or skeletal traction.

An abductive splint is not applied to persons with disturbed cardiovascular activity, to very obese people, and to senile individuals with impacted adductive fractures coupled with displacement, treatment being limited to a sling with a large cotton cylinder fitted in the axilla.

Application of an abductive splint is contraindicated in the presence of abductive fractures with a small distortion angle (the angle is open outward), since in this case the distortion would increase even more and the fragments may separate. The arm is suspended in a triangular bandage in the presence of such fractures. When abductive fractures of the neck of the humerus occur in children and middle-aged persons, first the bone is repositioned by pulling along the length of the humerus and adducting it, raising the elbow upward and forward over the costal arch, and rotating the forearm outward. In this case an assistant presses his wrist, which is pushed into the armpit, against the proximal part of the peripheral fragment. Next a triangular bandage is applied with a cylindrical pad in the armpit, and therapeutic physical culture is prescribed.

In a number of cases of fractures of the neck of the humerus involving considerable displacement, and especially of complete detachment of the head, with or without its dislocation, fragments can be repositioned correctly only by surgery. The repositioned head of the humerus is secured with a metallic or bone pin, spokes, or a Kaplan-Antonov cornerplate (Figure 20).

An abductive splint is used together with adhesive extension of the shoulder in the presence of complete fractures of the tuberosity coupled with

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displacement. The position of the splint is the same as with fracture of the diaphysis of the humerus.

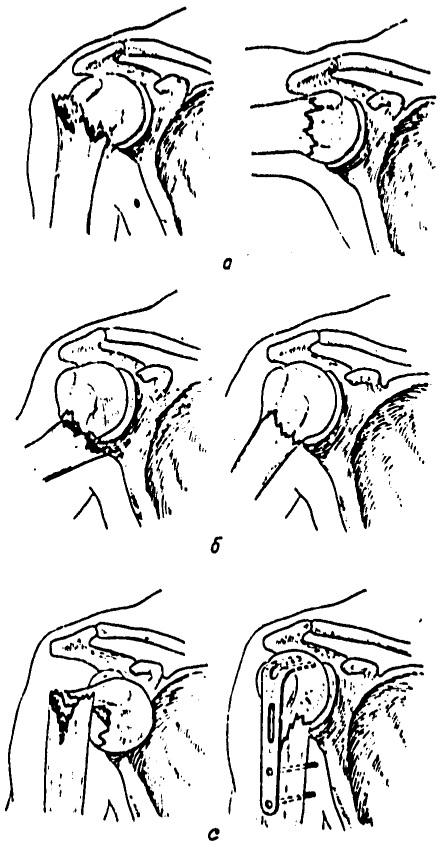

Figure 20. Typical Fractures of the Surgical Neck of the Humerus (Before and After Repositioning): *a*--adductive fracture; *b*--abductive fracture; *c*--fracture of the surgical neck of the humerus coupled with total detachment of fragments; osteosynthesis using a Kaplan-Antonov cornerplate.

If a check X-ray taken on the 2d-4th day shows that the detached tuberosity of the humerus had not been returned to its place, surgery is indicated when displacement is considerable. A detached tuberosity can be stitched in place by two silk sutures passing through soft tissues, or it can be

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secured with a nail or screw. The arm is placed in an abductive splint for 3-4 weeks after the operation.

In most cases fractures of the diaphysis of the humerus are accompanied by displacement of fragments, the extent of which depends on the level of the fracture and the degree to which the corresponding muscle groups contract.

Symptoms: Deformation and swelling are evident at the place of fracture, angular distortion is often present, and abnormal mobility and crepitation are observed. An attempt at active movement of the shoulder causes displacement of fragments, pain, and even greater shortening of the limb. Diaphyseal fractures, especially in the middle and lower divisions, are often accompanied by injury to the radial nerve. The clinical manifestation of such a fracture is hanging of the wrist and an inability to actively extend it and the proximal phalanges, as well as decreased sensitivity in the radial part of the wrist and the extensor surface of the forearm. Injury to the radial nerve is associated in most cases with its strangulation and compression, as well as with bleeding into its body; severing of the radial nerve is observed much more rarely. Injuries rarely occur to the median and ulnar nerves in the presence of fractures of the humerus. When examining the victim, the pulse of the radial arteries of both arms should also be compared.

First medical aid and treatment: Primitive immobilization consists of bandaging one or two boards or several sticks or tree branches, and so on, to the shoulder. The arm is suspended from a triangular bandage, or it is secured to the torso with a bandage. The victim is sent to the OPM, where a Cramer splint is applied if necessary to improve immobilization (see Figure 19). Two straps made from bandage material are tied to the corners of the upper end of the bent splint; after the splint is applied, the straps are tied to the corners of the lower end of the splint. The splint is then bandaged to the arm, which is bent at the elbow joint, from the healthy scapula over the shoulder of the injured side, and to the shoulder and forearm. The splinted injured arm is placed in a triangular bandage. When pain is intense, prior to application of the splint an adult patient is given 1 ml 1-2 percent promedol or omnopon solution or 20 ml 1-2 percent novocaine solution subcutaneously at the place of fracture. Antibiotics and tetanus serum should be injected simultaneously in the presence of compound fractures. All measures implemented are noted on the victim's appropriate medical card.

A victim with a shoulder fracture should be transported in seated position or lying down to a specialized traumatological hospital.

Specialized treatment, which follows clinical and X-ray examination, involves injection of 20 ml 1 percent or 2 percent novocaine solution in the area of the fracture. In all cases of compound fractures the wound is subjected to initial surgical treatment. Treatment of fractures of the diaphysis of the humerus involves skeletal traction using the area of the abductive splint beside the olecranon as the anchoring point; this is known as an "airplane"

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splint (Figure 21). The more centrally the fracture is located, the greater should be the angle of abduction of the humerus with an abductive splint, and the more peripheral the fracture is, the smaller this angle should be. For practical purposes, however, it would be suitable to use a 90° angle in all cases. An abductive splint used with fractures of the humerus must always be secured 30-40° forward of the frontal plane. When the fragments are in good condition and their position is stable, a plaster thoracobrachial cast can be applied (Figure 22). Fragments can also be secured with a compression-distraction apparatus. Knitting of slightly displaced fragments of a slightly shortened limb does not have noticeable negative influence on restoration of the limb's function.

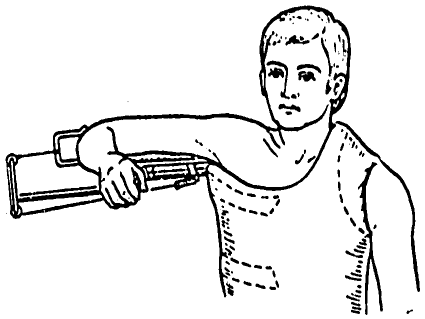

Figure 21. Skeletal Traction for Low Fractures of the Humerus Using an Abductive Splint and a Kaplan Arch

When the middle and lower thirds of the diaphysis of the humerus are fractured, paralysis of the radial nerve is often observed. It is very difficult to clarify the cause of paralysis or paresis of the nerve in the first days after trauma. In such cases a palmar plaster splint should be applied to the forearm and wrist with the purpose of keeping the wrist and fingers, at the metacarpophalangeal joints, in extended position. In most cases the paralysis gradually passes, if the condition of the fragments is good.

Surgical treatment is indicated when soft tissues are interpositioned and when check X-rays reveal that repositioning of fragments is not satisfactory. The humerus is subjected to osteosynthesis simultaneously with initial surgical treatment of wounds accompanying compound fractures, if the appropriate indications are present and if contraindications are absent. Surgery (neurolysis or suturing of an injured nerve in combination with osteosynthesis) is indicated when fragments are displaced and when paresis or paralysis of the radial nerve occurs. It would be most suitable to operate on victims with simple fractures on the 2d-5th day after trauma.

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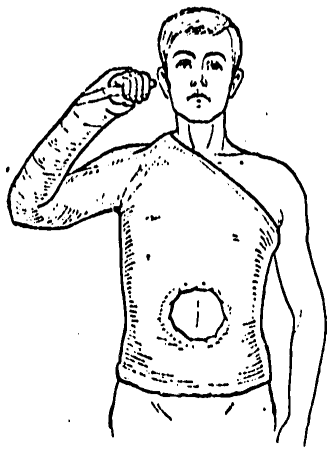

Figure 22. Thoracobrachial Plaster Cast Used to Treat a Patient with a Fracture of the Humerus

Fractures of the lower end of the humerus may or may not involve displacement. They are distinguished in relation to their mechanism as flexing and extending. They usually arise in response to a blow to the elbow. Such fractures are accompanied by bruises, sprains and, rarely, breakage of the ulnar, radial, and median nerves, as well as injury to blood vessels traveling through the elbow area.

Symptoms: Considerable swelling, deformation, and pain are observed around the elbow. Displaced fragments may crush or damage the median and ulnar nerves and the artery. These facts must be determined at the time of the victim's examination. The type of fracture is clarified with X-rays.

T- and Y-shaped fractures of condyles of the humerus are joint fractures, and they are a combination of supracondylic and intercondylic fractures of the humerus. Such fractures are also sometimes accompanied by fragmentation of the condyles of the humerus and the olecranon, or fracture of the condyles of the humerus is combined with dislocation and fracture of the forearm. T- and Y-shaped fractures are encountered less frequently among children than among adults.

An intercondylic fracture coupled with epiphysiolysis of the lower epiphysis of the humerus is treated as a joint fracture. Such a fracture is encountered almost exclusively in children and young people. The fracture line passes through the epiphyseal line and bears the nature of epiphysiolysis.

Fractures of the external condyle of the humerus are not infrequent; they are one of the frequent forms of elbow fractures in children. The fracture

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is caused by falling on the elbow or the wrist of an outstretched and abducted limb. Pressing against the capitellum of the humerus, the head of the radius chips off the entire external condyle and a small piece of the trochlea adjacent to the former.

In addition to fractures not involving displacement, we can observe fractures coupled with slight outward and upward displacement of the condyle. A severer form is a fracture in which a detached condyle shifts outward and upward, slips out of the joint, and turns its inner surface outward (by 90°).

Fracture of the internal condyle of the humerus is rare. Fracture of the capitellum may be isolated, or it may be combined with fracture of the head of the radius and with other joint fractures. Moving upward and forward, the head of the radius traumatizes the articular surface of the capitellum adjacent to it. In a number of cases we can observe separation of a significant part of the capitellum and the adjacent trochlea. The fragment shifts forward and upward.

Fracture and epiphysiolysis of the internal condyle of the humerus occur mainly in response to sudden and forceful abduction of the extended forearm. When such a mechanism of injury is involved in children aged from 7 to 17 years, the condyle separates along the epiphysial line. Sometimes the separated condyle, which is joined to the internal lateral ligament, jams itself between the articular surfaces of the olecranon and the trochlea of the humerus, pulling the ulnar nerve with it. Separation of the internal condyle is also observed with dislocation of the elbow joint.

Fracture and epiphysiolysis of the external condyle of the humerus are observed much more rarely than those of the internal condyle. Separation of the external lateral ligament together with a small plate of bone from the outer condyle of the humerus is what usually happens. Displacement is usually slight.

Fracture of the olecranon is a joint fracture, and it arises in response to a direct blow against a hard object; detachment of the summit of the olecranon owing to forceful contraction of the triceps muscle is observed much more rarely. In most cases the fracture line is transverse, and it usually passes close to the base or through the middle of the olecranon. Among children, fracture of the olecranon is predominantly observed with the older ones. We distinguish between fractures with displacement and without displacement.

Symptoms: Swelling, bleeding, and pain are observed in the vicinity of the olecranon. When fracture involves displacement, a wide transverse groove can be felt between the fragment drawn upward and the upper end of the ulna. Active flexion in the elbow joint is possible. Active extension is impossible.

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Fracture of the coronoid process of the ulna is observed most often with rearward dislocations of the forearm. We also encounter isolated fractures in response to abrupt contraction of the brachialis anticus muscle, the tendon of which attaches to the coronoid process. In most cases the fragment is small, and displacement is insignificant.

Symptoms: Swelling and pain are observed in the elbow area in response to flexion in the elbow joint.

Fracture of the head and neck of the radius arises as a result of falling on the outstretched arm, which causes contusion and wedging of the head of the radius into the capitellum of the humerus. In such cases we often observe not only fracture of the head of the radius but also injury to the cartilage of the capitellum, which a roentgenological study does not always reveal. We distinguish between three types of fractures of the head of the radius: 1) Cracks and fractures without displacement; 2) marginal fractures coupled with displacement; 3) comminuted fracture of the head of the radius. Isolated fracture of the neck of the radius is usually encountered among children 8-12 years old. When the neck of the radius is fractured in children, even if the entire head is displaced, the radius remains whole, and its comminution is rarely observed.

Symptoms: Swelling and a hematoma are noted around the head of the radius. Palpation of and pressure on the head of the radius do not cause pain. Active and passive flexion and rotation of the forearm are possible but limited in volume; rotations of the forearm are possible but limited, and they elicit sharp pain in the area of the head of the humeroradialis articulation; crepitation is sometimes felt.

First medical aid and treatment: When fractures occur in the area of the elbow joint, a layer of cotton is applied and bandaged to the elbow joint, the lower part of the upper arm, and the upper part of the forearm. The elbow joint is immobilized with a standard or improvised splint. The arm is suspended in a triangular bandage. Victims are sent to an OPM, where immobilization is improved as necessary. When pain is intense an adult is given a subcutaneous injection of 1-2 ml 1 percent promedol or omnopon solution or 20 ml 1-2 percent novocaine solution at the place of fracture. In the presence of compound fractures antibiotics and tetanus serum must be injected simultaneously. All measures implemented are noted on the victim's appropriate medical card. Next the victim is transported to the hospital base for specialized traumatological aid.

Roentgenological study must follow clinical examination. X-rays must be taken in the anteroposterior and lateral directions. In all cases of compound fractures the wound is subjected to initial surgical treatment.

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All fractures of the elbow joint not involving displacement of fragments are treated by application of a plaster splint on the extending surface of the upper arm, forearm, and wrist. The forearm is secured bent at a right angle. The plaster splint is removed from children after 7-10 days and from adults after 15-21 days, after which unforced movement in the elbow joint is started.

Fractures involving displacement of fragments must be repositioned. The sooner repositioning is performed, the easier and better it is. An injection of 20 ml 1-2 percent novocaine solution is made at the place of fracture on the extending surface of the upper arm. It would be best to use anesthesia when repositioning fractures of children and persons with well developed muscles.

Repositioning of epicondylic fractures and of T- and Y-shaped transcondylic extending fractures of the humerus involving displacement of fragments: Immediate repositioning of an extending epicondylic fracture involving displacement of fragments proceeds as follows: 1) The surgeon's assistant grasps the victim's forearm in its lower portion and in the area of the radiocarpal joint with one hand and pulls the limb along its axis, concurrently rotating the prone forearm upward. A counterpull is created on the shoulder; 2) to reposition a lower fragment which had shifted rearward and inward in the presence of an extending fracture, the surgeon places one of his wrists on the outer anterior surface of the lower part of the upper fragment, holding it down, and the other wrist on the posterior internal surface of the lower fragment, shifting it forward and outward. Concurrently the limb is flexed at the elbow joint to a 60-70° angle. After the limb is placed in this position a reinforced plaster cast is applied to the upper arm and forearm. A cotton pad is first placed at the bend of the elbow between the upper arm and forearm. Immediately after this, before the anesthesia has worn off or the victim awakens, a check X-ray is taken. If repositioning was unsuccessful another attempt should be made to reset the fragments. It should be noted at the same time that numerous attempts at resetting are excessively traumatic to tissues and harmful.

The state of the limb's blood supply should be checked in the first hours and days after application of the plaster cast. When pains are intense and symptoms of impaired blood supply are present, the plaster cast should immediately be cut along the entire limb, and its edges should be parted.

After an extending epicondylic fracture of the humerus is set in children, plaster casts should not be applied. It would be sufficient to place a plaster splint on the upper arm and forearm, bent at the elbow joint to a 70-80° angle. The plaster splint is secured with a simple bandage, and the arm is slung in a triangular bandage.

Setting a flexing epicondylic fracture with displaced fragments in a single procedure: The lower part of the victim's forearm and the area of the radiocarpal joint are grasped with one hand, and a pull is applied to

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the bent forearm along the limb axis, constantly straightening the forearm until it is completely extended. The forearm is concurrently placed in supine position. A counterpull is created on the upper arm. To correct displacement of the lower fragment forward and inward, the surgeon's assistant pulls the limb while the surgeon places one wrist on the outer rear surface of the injured arm level with the lower end of the upper fragment, and with his other hand he applies a rearward and outward pressure on the anterior inner surface of the lower fragment.

The set fragments are secured with a dorsal plaster splint, which is applied to the extending surface of the arm, which is not extended at the elbow joint.

To prevent edema the arm of the victim, who must be confined to bed for the first 2-3 days, is suspended vertically, and later, when he begins to walk, it is elevated on a pillow during times of rest and sleep. After 2-3 weeks, and after 7-10 days for children, the plaster splint is removed and movement of the elbow joint is started.

Extending and flexing epicondylic fractures and transcondylic T- and Y-shaped fractures of both condyles of the humerus are treated by skeletal traction using the olecranon area of an abducting splint as the anchoring point if the bone cannot be set in a single procedure or if a plaster splint cannot keep the set fragments in place.

Beginning with the first days the victim must actively move his fingers and perform movements in the radiocarpal joint. Two weeks later, after initial knitting of the fragments takes place, a plaster splint is applied, securing the arm in the position described above. Four weeks later the plaster cast is removed, and movement in the elbow joint is prescribed.

Surgical treatment of epicondylic and T- and Y-shaped transcondylic fractures is resorted to when the bone cannot be set by the methods described above.

Setting lower epiphysiolysis of the humerus. The surgeon places one palm on the extending surface of the lower part of the humerus, and with the other he presses the lower epiphysis of the humerus rearward on the side of its flexing surface. In this case the forearm should be in extended position. After the setting procedure the arm of a child, which is extended at the elbow joint, is secured with a plaster splint for 8-10 days. Then gradual movements are begun in the elbow joint.

Setting a fracture of the external condyle involving outward displacement of a fragment and slight rotation of the detached condyle: The surgeon's assistant places his hand on the inner surface of the elbow, and with his other hand he grasps the victim's hand above the radiocarpal joint, pulling the arm along its axis and adducting the forearm. Thus the elbow is placed in a slight varus position, and more space is created over the upper half of the elbow joint. The surgeon places both of his thumbs on the fragment,

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pushes it upward and inward, and jams it into its former place. Next the surgeon places his hands on the anterior and rear surfaces of the condyles of the humerus, and next on the lateral surfaces, compressing them together. The elbow gradually flexes to a right angle; after this the surgeon once again squeezes the condyles together and applies a plaster cast to the shoulder, forearm, and wrist. The elbow is anchored at a 100° angle, while the forearm is set in a position halfway between pronation and supination. If repositioning is successful, the cast is removed from adults in 4 weeks, while a plaster splint is removed from children in 2 weeks. If the check X-ray shows that the fragment was not repositioned successfully, surgical setting would be indicated.

Fracture of a significant part of the capitellum involving forward and upward displacement of the fragment: The victim lies on the operating table with his arm extended in the elbow joint. The surgeon's assistant grasps the forearm above the wrist and extends the elbow joint. The flexing surface of the arm must be turned upward. The surgeon places his bent leg on a footstool, places the victim's elbow on his knee, and presses the fragment downward and rearward into its seat with his two thumbs. Then he bends the elbow to a right angle and applies a plaster cast to the upper arm and forearm, the latter being pronated. In a number of cases the repositioned fragment would best be secured with the elbow completely extended. If the check X-ray shows that the condition of the fragments is good, the plaster cast is left in this position for 3-4 weeks, after which movements in the elbow joint are prescribed. If the check X-ray shows that the fragment had not been repositioned successfully, surgical setting would be required.

When fractures or detachment of the epicondyle along the epiphysial line occur without its displacement or with its slight displacement to the level of the articular cleft, a plaster splint is applied, securing the elbow at a right angle and the forearm in a position halfway between pronation and supination. The plaster cast is removed in 1-2 weeks.

In cases where the internal condyle is significantly displaced or jammed into the elbow joint, immediate surgery is indicated.

Fractures of the olecranon: If a lateral X-ray taken with the elbow bent shows that the olecranon is fractured without displacement and that the fragments line up well, a plaster cast is applied to adults and a plaster splint is applied to children, on the upper arm and forearm with the elbow bent. If a lateral X-ray shows insignificant divergence of the fragments in response to bending of the forearm and this divergence disappears when the forearm is extended and pressure is applied to the olecranon (confirmed by a check X-ray), a plaster cast is applied to the upper arm and forearm straightened at the elbow for 2-3 weeks. The plaster splint can be removed from children in 7-10 days.

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Surgery is indicated in the presence of fractures of the olecranon involving separation of the fragments, as well as when a gap of at least 5 mm remains between the fragments when the elbow is extended. In the operation, the olecranon is connected to its base with a silk or wire suture, or a long screw (Figure 23). Following suturing of the olecranon, the forearm should be secured with the elbow joint in the position at which it was located during osteosynthesis; otherwise a gap may remain between the fragments. The best position is one in which the elbow is flexed at a 100° angle. The plaster cast is removed in 2-3 weeks.

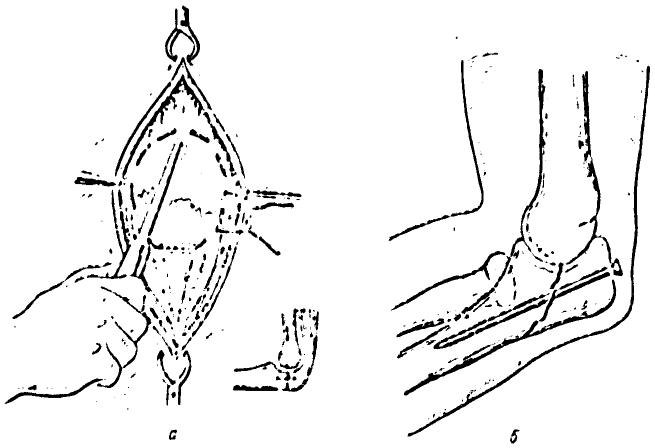

Figure 23. Osteosynthesis of a Fractured Olecranon: *a*--A hole is drilled into the olecranon; the fragments are brought together with a single-toothed hook and secured with a circular suture; *b*--the fragments are brought together and connected with a long wood screw.

When fractures of the coronoid process occur, a plaster cast is applied to the upper arm and forearm bent at the elbow at a 100° angle. The cast is removed after 10-18 days. In a number of cases, when displacement of the coronoid process is considerable, surgical setting and anchoring of the fragment is required.

When the head and neck of the radius are fractured without displacement or cracked, a plaster cast is applied from the middle of the upper arm to the metacarpophalangeal articulation with the elbow bent at a 90-100° angle. The forearm is secured in a position halfway between pronation and supination. The plaster cast is removed after 2 weeks, and dosed flexion, extension, and rotation of the forearm are prescribed. Children with fractures of the neck of the radius not accompanied by displacement or accompanied by slight

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displacement must wear a plaster splint for 7-10 days. If displacement of the head of the radius is complete or incomplete in children and the head is rotated so much that all or a large part of the articular surface is not in juxtaposition with the coronoid process of the humerus, an attempt must be made at repositioning, best under anesthesia. For this purpose the child's wrist is pulled while a counterpull is applied to the shoulder. The forearm is turned outward at the elbow to widen the space between the coronoid process of the humerus and the ulna. At this time the surgeon applies inward and upward pressure to the head of the radius. If the check X-ray shows that the head of the radius is set, a plaster splint is applied to the upper arm and supinated forearm, with the elbow bent at a 90-100° angle.

Surgery is indicated for adults with marginal fractures involving displacement and with comminuted fractures of the head of the radius. Surgery must be performed on the 1st-5th days after trauma. Resection of the head of the radius in indicated for adults in all cases. After the operation the forearm is placed in a position halfway between pronation and supination, and the elbow is bent at a right angle. A plaster cast is placed on the arm in this position for 12-14 days.

Surgery is indicated for children suffering fractures of the neck and head of the radius even with complete detachment of the head, if repositioning was unsuccessful without surgery.

Fractures of Forearm Bones

Fracture of the diaphysis of forearm bones is usually caused by direct trauma. Both bones of the forearm break at the same or at different levels. Incomplete green-stick fracture is observed among small children, while subepiphyseal fractures, often coupled with angular distortion, are observed among older children. Displacement of fragments is observed less frequently in children than in adults.

Fractures of the diaphysis of both forearm bones is observed more frequently than fractures of just one bone. Fracture of the diaphysis of the ulna is often accompanied with dislocation of the head of the radius (Monteggia's fracture), while a fracture involving displacement of the lower division of the diaphysis of the radius is often accompanied by dislocation or subluxation of the lower end of the ulna. Prompt diagnosis and setting of these dislocations have extremely important significance to the prognosis.

Symptoms: Deformation, swelling, pain, and abnormal mobility are observed in the area of fracture. The injured forearm is shorter than the healthy one. Forearm fracture not involving displacement and subepiphyseal fractures not involving distortion of the shaft are more difficult to identify in children. Swelling is usually present at the place of fracture, and pressure on this area causes pain.

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First medical aid and treatment: An immobilizing dressing is applied to the arm, bent in the elbow joint at a right angle, from the middle of the forearm to the base of the fingers. A Cramer splint or a mesh splint as well as plywood boards, cardboard, and so on can be used for this purpose. The victim is sent to the OPM, where immobilization is improved as necessary. Then it would be suitable to give a hypodermic injection of 1 ml 1-2 percent promedol or omnopon solution or 20 ml 1-2 percent novocaine solution to adults at the place of fracture. When compound fractures are present antibiotics and tetanus serum must be administered simultaneously. All of these measures are noted on the victim's appropriate medical card. He should be evacuated in seated position for special traumatological aid in institutions of the hospital base.

X-rays are taken in two planes in the specialized treatment stage, after clinical examination. When just the ulna is fractured the elbow should be X-rayed in order to permit prompt identification of a dislocation of the head of the radius. When just the radius is fractured an X-ray should be taken of the radiocarpal joint in order to clarify whether or not the head of the ulna is dislocated. In all cases of compound fractures the wound is subjected to initial surgical treatment.

Treatment of fractures of the diaphysis of both forearm bones not involving fragment displacement involves application of an unpadded plaster cast, applied to the upper arm and forearm bent at a right angle. The cast is removed after 6-8 weeks. During this time the patient must perform active movements with the fingers and shoulder joint.

The shaft of the humerus of children suffering subepiphyseal fractures not involving displacement and distortion is immobilized by application of a single plaster splint over the extending surface of the upper arm, the forearm bent at the elbow to a right angle, and the wrist. The arm is slung in a triangular bandage. The splint is removed in 3-4 weeks.

Treatment of fractures of the diaphysis of both forearm bones involving fragment displacement involves repositioning under local anesthesia using 20-30 ml 1-2 percent novocaine solution, intraosteal anesthesia, or general anesthesia. It would be best to set the bones with the help of special stretching apparatus; if the latter is unavailable, the bones are repositioned manually.

Manual bone setting: The assistant pulls the victim's thumb with one hand and the second through fourth fingers with the other. In order that the fingers would not slip from his grasp, they are smeared with kleol and one napkin is glued around the thumb and another is glued around the second through fourth fingers. A counterpull is applied to the upper arm. During traction the arm is abducted to a right angle. When fractures are present in the upper third of the forearm the latter is supinated, while when the fractures are in the middle and lower thirds it is placed in a position

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halfway between supination and pronation. After the fragments are set and before traction is removed, an unpadded plaster splint is applied to the upper arm and forearm. After this a check X-ray is taken. Secondary displacements of fragments often occur even after the plaster splint is molded well to the shape of the arm. This is why a check X-ray must be taken of the fracture within the plaster cast 2 weeks after the fragments are set.

To prevent edema the arm is elevated on pillows, or it is suspended from a rod. The victim should be kept under observation after the plaster cast is applied. If he complains of pain and a burning or numbing sensation or if other symptoms are present indicating impaired circulation, the plaster cast is immediately cut. Impaired circulation can lead to development of ischemic contracture and even to death of the limb; this is why pains should not be deadened by narcotics in such cases. On the day following the setting procedure and application of the plaster cast, the victim begins performing active movements in the fingers; after 3-5 days he begins movement in the shoulder joint. Victims must be taught to rhythmically flex and relax the muscles of the upper arm and forearm within the plaster cast. The latter is removed after 2.5-3 months. Early removal of a plaster cast--before knitting of the fracture--would be a mistake, since secondary displacement, distortion of the forearm, and formation of false joints could occur.

Subepiphyseal fractures of forearm bones coupled with angular distortion in children can be set under local anesthesia. For this purpose the surgeon places one of his wrists on the summit of the curvature of the forearm; grasping the distal portion of the child's forearm with his other hand, he gradually corrects the distortion, applying only a small force. Slight crepitation is often heard in this case. Then a dorsal plaster splint is applied to the upper arm and forearm bent to a right angle in the elbow joint. When children suffer fractures involving displacement of fragments, the setting procedure should be performed under anesthesia. The bones are repositioned by pulling the fingers and applying a counterpull to the upper arm. Repositioning is believed to be satisfactory and to not require resetting if longitudinal displacement is corrected, angular distortion is eliminated, and the axis of the forearm is straight even though the fragments are not in contact along the entire breadth of the fracture. Resetting must not be resorted to in these cases; instead, a plaster splint should be applied to the extending surface of the upper arm, forearm, and wrist. The elbow must be arrested at a right angle, and it would be better to supinate the forearm. Sometimes an additional splint is applied to the palmar surface of the forearm of older children. The splint is removed in 4-7 weeks. Longer immobilization is required with fractures in the middle third and when the fragments are not repositioned precisely, since in these cases repeat fractures are observed in children.

Treatment of fractures of the diaphysis of the ulna without displacement in adults involves application of a plaster cast to the upper arm, forearm, and wrist, with the arm bent at a 90-100° angle at the elbow; this cast is worn for 6-8 weeks. Children wear a plaster splint for 15-30 days. When

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fractures involve displacement and if X-rays do not show dislocation of the head of the ulna, the ulna is repositioned by traction, and then a plaster cast is worn for 8-10 days. Treatment of children following repositioning of the fragments is limited to application of a plaster splint for 3-5 weeks.

An extending fracture of the ulna coupled with forward dislocation of the head of the radius is set under local or general anesthesia, and a plaster cast is subsequently applied. Following stretching of the forearm, the head of the radius is pressed backward with the wrist. At this time the surgeon supports the elbow with the other hand to provide counterpressure. The elbow is flexed at a 90-100° angle. A plaster cast is applied with the arm in this position from the middle of the upper arm to the metacarpophalangeal articulation. The forearm is secured in a position midway between pronation and supination. A roentgenological check is mandatory immediately after setting and 2-3 weeks later, since repeat dislocation of the head of the radius and displacement of ulnar fragments are possible. The plaster cast is removed in 8-10 weeks, and active movements in the elbow are prescribed.

It would be better to set a flexed fracture of the upper third of the ulna with the arm extended. With the arm in this position and the victim lying on the table, the surgeon's assistant pulls the wrist while applying a counterpull to the upper arm. The dislocated head of the radius, which is displaced rearward, is simultaneously set by the surgeon by placing his wrist on the palmar side while at the same time trying to move it in the direction of the longitudinal axis of the radius. A counterpressure is applied with the other hand on the elbow flexure. As a rule it is easy to set the head of the radius by this means. Continuing to maintain traction, after this the fragments of the ulna are set by means of pressure on the back side of the distal fragment. After the forearm is supinated and the arm is extended at the elbow joint, a plaster splint is applied to the extending surface of the upper arm, forearm, and wrist. The splint is bandaged with two plaster bandages. This keeps the set fragments of the ulna and the dorsally dislocated head of the radius in place well. After 3 weeks the cast is removed and the forearm is gradually bent to a right angle in two or three procedures, each time being secured with a removable plaster splint applied to the extending surface of the arm. An X-ray check is mandatory immediately after setting and 3 weeks later. To avoid contracture the patient must begin movements in the shoulder joint and fingers as well as rhythmic tension and relaxation of muscles of the upper arm and forearm within the plaster cast within the very first days. After 8-10 weeks the plaster cast is removed and therapeutic physical culture is prescribed.

Monteggia's fractures are encountered less frequently among children than among adults. Usually after the head of the radius is set its fragments are returned to their proper position. Then a plaster splint is applied for 3 weeks.

Fractures of the diaphysis in the upper and middle thirds of the radius not involving displacement of fragments are treated by application of a plaster

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cast to the upper arm and forearm with the elbow bent at a right angle. The forearm is secured in supine position. When fractures occur in the lower third the plaster cast is applied up to the elbow joint, with the forearm midway between pronation and supination. The cast is worn for 6-8 weeks. Children wear a plaster splint for 2-4 weeks.

When fractures of the diaphysis of the radius are accompanied by displacement of fragments, the bone is set following the same procedure used with fractures of both forearm bones. The head of the ulna is easily set. A plaster cast is applied to the upper arm and forearm with the latter at a right angle; the forearm is placed in a position midway between pronation and supination. When applying the plaster cast care should be taken to see that the head of the ulna is set when secured; otherwise surgery would sometimes be required.

Surgery has great significance to adults with fractures of the diaphysis of the forearm bones, since it is often difficult to set and keep the fragments in place. Osteosynthesis should be performed in all cases of unstable fractures, as well as if check X-rays show that good setting had not been achieved. It would be better to operate immediately after unsuccessful repositioning of the fragments, or on the 2d-5th days after trauma. In the event of compound fractures of the forearm, if the appropriate indications are present and contraindications are absent, osteosynthesis is performed simultaneously with initial surgical treatment of wounds.

Fractures of the lower end of the forearm bones: Fracture of the forearm usually occurs in the lower epiphysis of the radius, known as a "typical forearm fracture" or a Colles' fracture. Women, usually elderly, make up the bulk of victims with such fractures. Extensional fracture of the ulna occurs in the typical place in response to a fall on an outstretched arm. The plane of fracture is usually 1-2 cm proximal to the lower articular surface of the radius. The peripheral fragment is compressed and displaced radially and dorsad.

Owing to impaction of the central fragment into the peripheral fragment, fractures of the lower end of the radius are often impacted fractures. There are two types of injury to the lower epiphysis--circumarticular, in which the epiphysis of the radius remains whole, and articular, when the epiphysis undergoes comminution. The prognosis is worse with articular epiphyseal fractures of the radius, especially if its epiphysis is considerably fragmented.

The flexional type of fracture, the mechanism of which is opposite that of a typical Colles' fracture, is observed much more rarely. This fracture is known as Smith's fracture. It is caused by a fall on the dorsal rather than the palmar surface of the wrist. In these cases the peripheral fragment is displaced in the palmar direction and shifter dorsad.

Fractures in the distal end of the forearm are often observed in children. The plane of the fracture occurring in small children falling on the wrist

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is usually somewhat above the epiphyseal line, passing along the metaphysis of the radius. Epiphysiolysis is observed in older children and adolescents. But epiphysiolysis usually occurs together with fracture of the metaphysis; the plane of fracture in these cases first proceeds from the elbow side of the radius along the epiphyseal line, and then to the radial margin through the metaphysis of the radius. These injuries may occur without displacement and, in a number of cases, with considerable displacement. Detachment of the styloid process of the ulna is not observed with such fractures in children. In these cases older children experience infraction or fracture of the lower metaphysis of the ulna.

Fractures occurring in the typical place may or may not be accompanied by displacement.

Symptoms: Deformation of the distal end accompanying fracture of the lower epiphysis of the forearm has a typical bayonet shape. With an extensional fracture, the dorsally displaced distal fragment can be seen to bulge out on the dorsal surface, immediately above the radiocarpal joint. The wrist and the lower fragment are tilted in the direction of the radius. Swelling corresponding to location of the displaced distal end of the central fragment is noticeable on the palmar surface.

With a flexional fracture, protrusion of correspondingly displaced fragments on the dorsal and palmar surfaces of the forearm is opposite in nature. Movements in the radiocarpal joint are extremely limited.

It is much more difficult to identify a fracture that is not accompanied by displacement; only swelling and pain in response to pressure are noticeable at the place of fracture. X-rays taken in two planes have the decisive significance.

First medical aid and treatment: When injuries occur in the area of the radiocarpal joint, a splint made from plywood boards, wire mesh, or cardboard is applied. The arm is slung in a triangular bandage. The victim is sent to the OPM, where immobilization is improved as necessary. When compound fractures are present antibiotics as well as tetanus serum must be administered. All measures implemented are noted on the appropriate medical card of the victim. He must be evacuated in seated position to institutions of the hospital base for specialized aid. After clinical examination, X-rays must be taken in two planes. It is only on the basis of X-rays that we can make a differential diagnosis and render qualified traumatological aid.

Typical forearm fractures are set under local anesthesia using 20 ml 1-2 percent novocaine solution. When the fracture does not involve displacement the forearm is secured in a position midway between pronation and supination with a dorsal plaster splint. In this case the wrist is flexed slightly dorsally. The plaster splint is removed in 3 weeks. A dorsal splint is worn by children for 10-18 days.

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A fractured radius accompanied by displacement is easily set manually or with special apparatus. In the absence of stretching apparatus, fragments can be repositioned well with the manual method.

In manual setting the first through fourth fingers of the patient, which will be pulled to set the bone, are smeared with kleol so that they would not slip; the thumb is bandaged separately, and the second, third, and fourth fingers are bandaged together; the fifth finger is left free. Traction is applied to the thumb and separately to the second, third, and fourth fingers. A counterpull is applied to the upper arm. When the manual method is employed the surgeon's assistant must apply traction to the fragments for about 5 minutes. After this, when the distal fragment is displaced toward the radius and dorsad, while maintaining traction the surgeon places one hand beneath the lower end of the central fragment on the palmar side, he places the other hand on the dorsal side of the peripheral fragment, then he moves his hand to the lower part of the forearm on the ulnar side, and forcefully flexes the wrist in the ulnar direction; next the wrist is pronated. The assistant continues to apply traction to the forearm until the plaster dressing is on. The deep dorsal plaster splint must cover two-thirds of the forearm and the radiocarpal joint, arresting the wrist with a slight palmar flexion and abducted slightly. The plaster splint should be well molded and secured with a gauze bandage. After the splint sets firmly, traction is terminated. The position of the fragments is checked with X-rays taken at this time (Figure 24). In the event of a Smith fracture, where the peripheral fragment is displaced in the palmar direction, the bone is set with pressure applied to the lower end of the central fragment in the palmar direction, and with forceful dorsal flexion of the wrist. The plaster splint is applied with the arm in this position. After the splint is applied the victim remains under observation for the first 8-12 hours. If phenomena of disturbed circulation arise, the gauze bandage on the palmar side is cut and the edges of the splint are separated slightly from the skin. Then the splint is immediately rebandaged with another gauze bandage. Two to four days after swelling decreases the splint is secured with a plain or plaster bandage. In view of the fact that secondary displacement could have occurred when swelling decreased, check X-rays must be taken after 7-10 days. Victims must begin active movement with the fingers in the very first day: The success of treatment depends on this. Patients must be kept under observation in the first days, since otherwise the fingers may become stiff with time due to prolonged edema of the fingers and a fear of moving them. The plaster splint is removed in 4-5 weeks. Therapeutic physical culture, mechanotherapy, massage, and heat treatments are prescribed.

When fractures occur in the lower epimetaphysis of the radius without displacement, children must wear a dorsal plaster splint on the forearm for 10-15 days. When epiphysiolysis and fractures of the lower metaphysis occur together with displacement, it would be best to set the bones under anesthesia. After repositioning, a dorsal plaster splint is applied and a check X-ray is taken. The splint is removed in 15-21 days. Injury to the epiphyseal cartilage may have a negative effect on bone growth, causing

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deformity if the fragments are not repositioned in time. Minor displacements in the area of the metaphysis of the radius correct themselves completely as children grow.

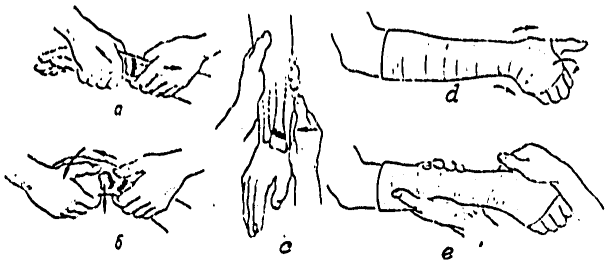

Figure 24. Setting a Typical Flexional Fracture of the Forearm (*а, б, в*) and Applying a Plaster Splint or Cast (*г, д*).

Fractures of Wrist and Finger Bones

Fracture of the scaphoid occurs mainly due to falling on a dorsally flexed and radially abducted wrist. As a rule the scaphoid bone breaks into two parts.

Fractures of the scaphoid usually combine with typical fractures of the forearm or perilunar dislocation.

Fractures of the scaphoid are often missed. This diagnostic error leads to severe consequences taking the form of pains, restriction of the functions of the radiocarpal joint, and reduction of the victim's ability to work.

Symptoms: Swelling and pains in response to pressure are located in the area of the "anatomical snuff-box." Sensitivity is especially pronounced in response to pressure applied directly beneath the styloid process of the radius.

Fracture of the semilunar bone: The semilunar bone can be fractured by a fall on the wrist abducted in the ulnar direction. Sometimes fracture combines with dislocation. In addition to isolated fractures of the semilunar bone we can observe fractures combined with dislocations and fractures of other carpal bones, and a typical fracture of the forearm. In most cases the fracture is compressional in nature, and the semilunar bone is crushed. Sometimes the bone's dorsal process separates off.

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There are two types of fractures of the base of the first metacarpal bone.

In the first type the fracture occurs only on the ulnar margin of the base of the first metacarpal bone. Together with the peripheral fragment of the metacarpal bone, the thumb is dislocated dorsoradially in the carpometacarpal joint; such a dislocation fracture is called Bennett's fracture.

In the second type a flexional fracture occurs at the base of the first metacarpal bone. The fracture line is 1.5 cm above the joint, and it does not penetrate into it. The distal part of the bone shifts and situates itself at an angle with its apex turned dorsally. In distinction from the first type of fracture, the second type is not an articular fracture.

Symptoms: The thumb rests in adducted position. A projection can be felt on the dorsal surface of its base. Palpation in this area is painful.

Fractures of the second, third, fourth, and fifth metacarpal bones can occur as a result of direct and indirect trauma at the base of the shaft and the head. In addition to fractures of one bone, we can observe fractures of two and more metacarpal bones. Fractures can exist with and without displacement of fragments. Usually with displaced fractures the fragments are at an angle with the apex pointing dorsally. Lateral displacement is observed when several metacarpal bones are fractured. In such cases soft tissues are often interpositioned between the fragments.

Symptoms: Bleeding occurs in the area of the fractures, and a bulge is sometimes seen on the back of the wrist. Fractures of the metacarpal bones can be identified more accurately with X-rays taken in two planes.

Fractures of the fingers: Fractures of the phalanges are often compound.

The phalanges are fractured predominantly by a direct blow. We distinguish articular fractures, circumarticular fractures, and fractures of the shank of the phalanx. A significant proportion of finger fractures occur at the base of the phalanx.

Interphalangeal dislocation fractures and sprains may be accompanied by detachment of a small piece of the articular eminence.

Fractures of the ungual phalanges are associated in most cases with direct trauma, for example a blow from a hammer. In such cases a comminuted fracture occurs, accompanied by a subungual hematoma. Forced flexion of fingers in a number of cases causes detachment of the tendon of the extensor indicis from its place of attachment to the base of the ungual phalanx; this is sometimes accompanied by detachment of a triangular fragment from the base of the phalanx.

Symptoms: Fracture coupled with displacement of fragments on the shank of the phalanx is characterized by deformation and shortening of the finger.

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When the angle of displacement of fragments is typical, a bony bulge can be felt on the palmar surface. Significant swelling and hemorrhaging cover up deformation, and palpation and tapping along the axis of the finger cause pain at the place of fracture.

Fractures of the phalangeal joints are accompanied by local swelling, and movements elicit sharp pain.

First medical aid and treatment: When the hand and fingers are injured and a wound is present, an aseptic dressing is applied. A dense wad of cotton wound in gauze is placed in the palm so that the fingers could be partially flexed. A splint--plywood, cardboard, or Cramer's--is applied to the forearm, wrist, and fingers. The victim is sent to the OPM, where immmobilization is improved as necessary. Antibiotics and tetanus serum are administered in the presence of compound fractures. All measures implemented are noted on the victim's appropriate medical card. He is evactuated in seated position to the hospital base for specialized aid.

An X-ray is taken after clinical examination. When the scaphoid is fractured the radiocarpal joint is secured straight with a slightly dorsal flexion and slight ulnar abduction of the wrist. A plaster cast is applied from the fourth and fifth heads of the metacarpal bones and the interphalangeal joint of the thumb to the elbow for 8-10 weeks.

Beginning with the first day after injury the victim must make active movements with his fingers and the entire arm. After the plaster cast is removed an X-ray is taken, and if the fragments have not mended, the same sort of plaster cast is applied for another 1-3 months.

When fractures of the semilunar bone occur and cracks are present, the plaster cast is applied to the forearm and wrist for 6 weeks. When the semilunar bone suffers comminuted (compressional) fractures immobilization is longer (8-10 weeks), though this is not often successful and it does not guarantee against development of aseptic necrosis and deformation of the bone.

Fractures of the base of the first metacarpal bone are set under local anesthesia. The surgeon's assistant holds the victim's hand by the second, third, and fourth fingers. The surgeon pulls the thumb alone and abducts the first metacarpal bone radially. Pressing on the ulnar side of the base of the first metacarpal bone, he simultaneously abducts it even more in the radial direction. In this case an unpadded plaster cast is applied together with a dorsal splint. In order to prevent redisplacement on the radial side of the base of the first metacarpal bone, the surgeon presses his finger into the plaster cast, forming a depression here. When there is a tendency for redisplacement after setting, a plaster cast is applied to the forearm and a wire splint is secured to it with a plaster bandage. Permanent skeletal traction is achieved with a thin stainless steel spoke or a special pin passed through the ungual phalanx of the thumb under local anesthesia

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(3 ml 0.5 percent novocaine solution). Traction is terminated after 10-15 days, and the plaster cast is removed after 4 weeks.

Fractures of the second, third, fourth, and fifth metacarpal bones not accompanied by displacement are treated with an unpadded plaster splint applied to the forearm and hand. When fractures involve dorsal angular displacement, after local anesthesia the surgeon's assistant pulls along the length of the appropriate finger. Then the surgeon presses his finger onto the dorsal side of the hand above the point of fracture and simultaneously presses his finger onto the palmar side of the head of the metacarpal bone, in the opposite direction. After this a plaster cast is applied. Active movements of the fingers and free joints of the arm are prescribed beginning on the first days. The plaster cast is removed in 2 weeks. When one or several metacarpal bones are fractured and displacement occurs, wire splints are secured to the cast with plaster bandage and bent 10-20° at the metacarpalphalangeal joint, 90° at the first interphalangeal joint, and 45° at the second. A stainless steel spoke or pin is passed through the phalanx. Fragments are set by traction applied to the appropriate finger, and they are held in place with an elastic bandage. The victim must begin moving all free fingers on the first day. The plaster cast is removed after 3 weeks.

If a check X-ray shows that a metacarpal fracture had not been set correctly and when fractures exhibit a tendency for displacement, it would be best to secure the fragments with stainless steel spokes. A plaster splint is applied to the forearm and hand. The spoke is removed after 2-3 weeks. Fingers should be moved beginning with the first day.

When fractures occur without displacement (the middle and ungual phalanges), the injured phalanx and the one next to it are immobilized with several layers of adhesive tape.

Fractures of the basal phalanx without displacement and of all phalanges with displacement are treated with elastic traction and without it. To achieve permanent traction a plaster cast is applied to the forearm and the radiocarpal joint is arrested. After the cast sets a wire splint bent 45° at the metacarpalphalangeal joint is secured to the cast with plaster bandage. When angular displacements occur, the fragments are set and the finger is secured to a wire splint with adhesive tape for 2 weeks. When considerable displacement occurs, 2-3 ml 0.5 percent novocaine solution are injected into the fingertip. A stainless steel pin or spoke is passed through the ungual phalanx and shaped into a small bracket; a rubber tube is tied to it, and then the fracture is set in one procedure. The wire passed through the fingertip and the rubber tube secured to it are stretched and tied to a thick wire specially secured to the palmar side of the plaster cast. The position of the fragments is checked on an X-ray. The victim must exercise all joints of the uninjured fingers as well as the elbow and shoulder joints beginning on the first days.

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The plaster cast is removed in 3 weeks.

If repositioning of fragments is unsuccessful, surgical correction would be required--arresting the fragments with spokes.

It is extremely important to set fragments when treating articular fractures of the phalanx. If the fragments cannot be repositioned, surgery would be indicated. Comminuted and unrepositionable articular and circumarticular fractures of the phalanges often lead to ankylosis, deformative arthrosis, contractures, and limitation of movements in finger joints. This must be considered when immobilizing the fingers. Immobilizing bandages are applied in a functionally advantageous position--that is, the broken finger is bent slightly at all joints before being arrested. In no case should a finger be straight when immobilized.

When fractures of the ungual phalanx are accompanied by subungual bleeding, the hematoma should be removed to avoid infection of the place of fracture. The nail is trepanated for this purpose.

Early initial surgical treatment of the wound has great significance to compound fractures of hand and finger bones. Excision of wound margins must be very economical, especially on the fingers. When the margins of an incised wound are even and the wound is clean, it need not be excised. Sloughed skin fragments still supplied with blood must be returned to their place. Torn tendons and nerves are sutured together only if the wound is clean after initial surgical treatment.

Initial dermatoplasty using local tissues and free dermatoplasty with a simple or perforated panniculus are indicated in the presence of a skin defect; initial dermatoplasty using a pedicle graft from the abdomen is indicated in a number of cases.

As far as treatment of the fracture itself of hand and finger bones is concerned, osteosynthesis is performed with thin spokes when the indications are present and contraindications and absent. Antibiotic therapy is provided in the postoperative period.

Lower Limb Bone Fractures

Fractures of the Femur

Fractures at the upper end of the thigh: The mechanism of fracture usually involves falling and contusion in the vicinity of the great trochanter. Medial fractures of the neck of the femur (articular) are usually observed; these are subdivided in turn into abductive (impacted) and adductive (non-impacted) trochanter fractures. Children experience subcapital epiphysiolysis of the femur and intertrochanteric fractures as well as fractures of the great and lesser trochanters (Figure 25).

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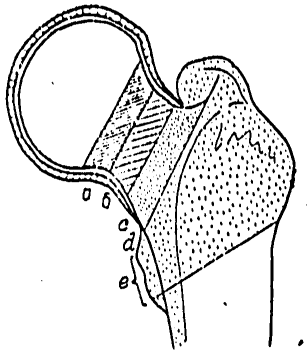

Figure 25. Fractures of the Neck of the Femur and Trochanteric Area: *a*--Subcapital; *b*--transcervical; *c*--basal; *d*--intertrochanteric; *e*--transtrochanteric.

Symptoms: Pain is not sharp in a state of rest and it intensifies with an attempt at movement. Pain is not great with impacted medial fractures. In contrast to the situation with medial fractures of the neck, trochanteric fractures of the femur are accompanied by swelling and a hematoma in the vicinity of the coxofemoral joint, spreading extensively over the outer surface of the upper third of the thigh. Outward rotation is typical of fractures of the upper end of the femur.

Outward rotation of the thigh is more pronounced with intertrochanteric and transtrochanteric fractures than with medial fractures.

Shortening of the limb by 2-4 cm is noted with fractures involving displacement. Shortening usually does not occur or it is slight (within 1 cm) in patients with impacted fractures. A certain lengthening of the limb (by up to 1 cm) due to enlargement of the cervicodiaphyseal angle is noted in a number of cases of abductive fractures of the neck of the femur. Patients with impacted medial fractures of the neck can sometimes continue to walk, though they experience pain in the coxofemoral joint. This can cause cleavage at the place of fracture, transforming an impacted fracture into a nonimpacted one.

First medical aid and treatment: An immobilizing dressing that arrests the coxofemoral, knee, and ankle joints must be applied to patients with fractures in the vicinity of the coxofemoral joint. It would be best to use a Dietrich splint, a Cramer splint, or long thin boards. The victim is sent to the OPM, where immobilization is improved as necessary. Then it would be suitable to give a hypodermic injection of 1 ml 1-2 percent promedol or

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omnopon solution or 20 ml 1-2 percent novocaine solution at the place of fracture. Antibiotics and tetanus serum must be administered concurrently in the presence of compound fractures. All measures implemented are noted on the victim's appropriate medical card. He should be evacuated in seated position to a specialized traumatological hospital.

X-rays should be taken in the hospital to permit establishment of the type of fracture. It should be remembered that sometimes with fresh impacted fractures of the neck of the femur the line of fracture is indistinct on the X-ray in the first days after trauma. In such cases X-rays should be retaken after 10-15 days. If a fracture is present, the line of fracture would be more distinct at this time.

Valgus or abductional medial fracture of the neck of the femur: A fracture of this sort is always impacted, and it knits well. A short hip cast is applied to the victim, who is permitted to walk about on crutches without placing weight on the afflicted limb. The cast is removed after 3-4 months.

Treatment of obese people, who have a poor tolerance of plaster casts, may consist of traction on a cradle with a 3 kg weight for 2 months. Placing weight on the leg must not be permitted until 6-8 months after trauma to prevent aseptic necrosis.

The principal method for treating medial adductional (nonimpacted) fractures of the femoral neck is abarticular osteosynthesis using a three-bladed pin. When an adductional medial fracture of the femoral neck is present, skeletal traction is applied to the femoral condyles or the tuberosity of the tibia using a 6-8 kg weight. Setting usually occurs on the 2d-3d day. The operation is performed on the 2d-5th day after trauma (Figure 26). Complications on the part of the heart, lungs, and so on must be prevented in the postoperative period. General and therapeutic physical culture have great significance in this period. Victims begin to walk 1-1.5 months after the operation, using crutches and without placing weight on the limb. To prevent aseptic necrosis of the head of the femur, the victim is not permitted to place weight on the limb until 6-8 months after trauma.

Subcapital epiphysiolysis of the femur in children: When epiphysiolysis is slight, adhesive tape traction or a hip cast is applied for 6-8 weeks. When epiphysiolysis is partial, an attempt could be made to set the fragment in one procedure under anesthesia, after which a hip cast is applied for 8-10 weeks. In some cases repositioning can be achieved by skeletal traction. Traction is employed for 2-3.5 months. Check X-rays often show that repositioning was unsuccessful. In these cases surgical repositioning should not be postponed, and osteosynthesis should be performed.

Treatment of intertrochanteric and transtrochanteric fractures by constant traction: A pin is inserted through the femoral condyles or the tibial tuberosity. When fractures do not involve displacement, the splint is not removed. A small weight is hung (4-6 kg). Traction is terminated after

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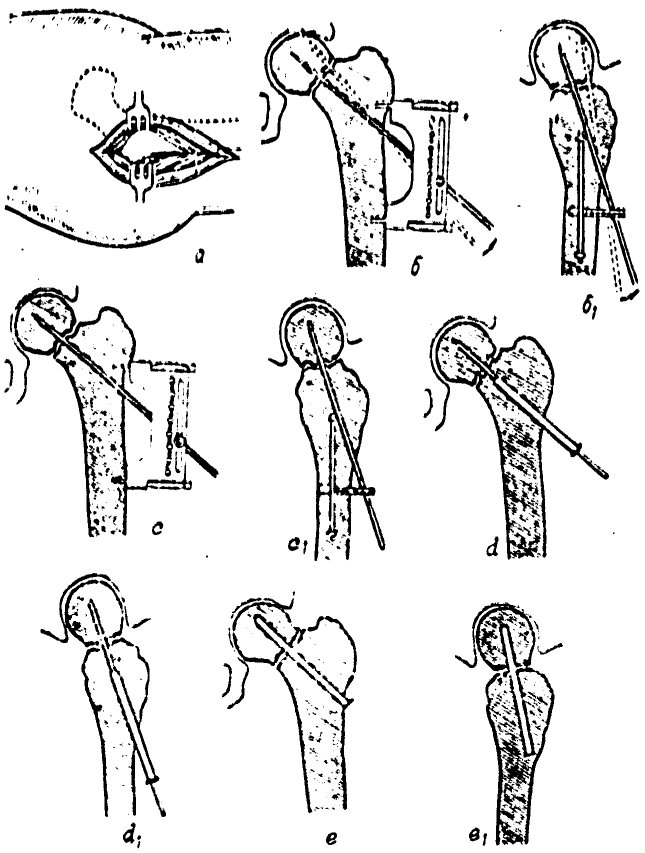

Figure 26. Kaplan's Procedure for Abarticular Osteosynthesis of a Femural Neck Fracture. Nonimpacted Medial Femoral Neck Fracture: *а*--Incision in the subtrochanteric area: A hole is drilled into the bone here; *б-б*$_1$--"guide table" secured to outer surface of femur; broken line shows incorrectly angled pin; *б*--anteroposterior position; *б*$_1$--lateral position; *в-в*$_1$--pin inserted correctly; *в*--anteroposterior position; *в*$_1$--lateral position; *д-д*$_1$--three-bladed pin inserted with a guide: *д*--anteroposterior position; *д*$_1$--lateral position; *е-е*$_1$--inserted three-bladed pin: *е*--anteroposterior position; *е*$_1$--lateral position.

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7 weeks. The patient is permitted to walk on crutches 2 months after trauma. Permission is given to place weight on the limb after 2.5 months.

When intertrochanteric and transtrochanteric fractures involve displacement, traction is applied with a weight of 8-10 kg. With intertrochanteric fractures the leg is allowed to lie without abduction, while in the presence of transtrochanteric fractures it is slightly or moderately abducted. Traction is terminated after 2.5-3 months. The patient is permitted to walk with crutches and place his full weight on the limb after 4 months.

Correcting outward rotation is the principal therapy for children suffering fractures involving no displacement or slight displacement. Traction may be cutaneous or skeletal; a 3-5 kg weight is applied for 3-4 weeks. When displacement is considerable a 4-6 kg weight is used for traction. It is important to correct outward rotation and prevent development of coxa vara. Traction time is 6 weeks. The patient is at first allowed to walk with crutches. Weight can be placed on the limb after 8-12 weeks.

A surgical method is often used with the elderly--osteosynthesis with a pin applied laterally during the time of treatment of intertrochanteric and transtrochanteric fractures. This affords victims the possibility for sitting soon after the operation and walking with crutches very soon after. Senile victims who must not be operated upon or treated by skeletal traction are laid in bed in the most comfortable position, and the limb is secured between two cylindrical sandbags. When outward rotation is considerable an attempt can be made to carefully correct it at least partially. The sandbags are placed such that they would prevent outward rotation of the leg. The same effect can be achieved by applying a cotton-padded plaster "boot" to the back of which a stick is secured horizontally with plaster bandages. After 5-6 weeks the patient is permitted to walk with crutches.

Isolated fractures of the great trochanter are infrequent. When fractures occur without displacement the leg is placed on a standard biplanar cradle. Fractures involving displacement of a fragment are treated by adhesive tape traction with a standard cradle, the leg being abducted and rotated outward. A small weight is employed (3-4 kg). Traction is applied to immobilize the limb; it is terminated after 10-15 days. The victim is permitted to walk with crutches an average of 14-20 days after trauma. When displacement of the great trochanter is considerable, surgery would be indicated. The great trochanter is fixed to its base by a metallic screw.

Isolated fractures of the lesser trochanter are extremely rare. When the lesser trochanter becomes detached, the leg is placed on a cradle for 2-3 weeks.

Fractures of the diaphysis of the femur occur due to both direct (contusion, crushing) and indirect (bending, twisting) trauma. Fractures in the area of the femoral diaphysis are distinguished as subtrochanteric fractures, fractures in the upper, middle, and lower thirds, and epicondylic fractures

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of the femur (Figure 27). The higher the fracture, the more significant the abduction and flexion of the proximal fragments; this pertains especially to subtrochanteric fractures and fractures in the upper third. Fractures in the middle third of the diaphysis are accompanied by less abduction and forward deflection of the central fragment.

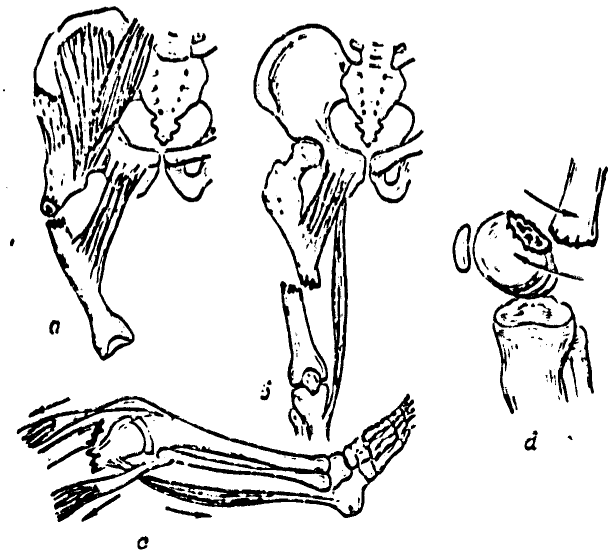

Figure 27. Typical Displacements of Fragments in Femoral Fractures: *a*--With subtrochanteric fractures; *b*--with fractures in upper and middle thirds; *c*--with fractures in the lower third and with epicondylic fractures; *d*--epiphysiolysis of femoral condyles in children.

When fractures occur in the lower third of the femur the peripheral fragment shifts rearward and upward due to muscle pull. The lower end of the central fragment shifts inward due to the pull of adductor muscles, locating itself in front of the peripheral fragment. The short lower fragment of an epicondylic femoral fracture may be rotated so far backward that the plane of the fracture faces the popliteal fossa. Because of such displacement of the lower fragment into the popliteal fossa, epicondylic femoral fractures are sometimes accompanied by crushing or injury to the neurovascular tract.

Epiphysiolysis is observed in the lower end of the femur of older children.

Symptoms: Pain, swelling, and mobility of fragments are detected in the area of femoral fracture. Below the level of fracture the bone is abruptly

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rotated outward. The femur is 4-6 cm shorter in most cases. An attempt to determine crepitation should not be made in an effort to refine the diagnosis, since this would traumatize surrounding tissues. When examining victims it is extremely important to promptly reveal injury to the neurovascular tract. For this purpose the pulse of peripheral vessels is taken and movement in the ankle joint and toes must be checked.

First medical aid and treatment: The leg is immobilized with a Dietrich splint, a Cramer splint, or an improvised splint. The coxofemoral, knee, and ankle joints should be arrested. The victim is sent to the OPM, where immobilization should be improved and a hypodermic injection of 1 ml 1 percent or 2 percent promedol or omnopon solution should be given, and a subcutaneous injection of 20 ml 1 percent or 2 percent novocaine solution should be made at the place of fracture. In the presence of compound fractures antibiotics need to be injected intramuscularly and anatoxin and tetanus serum should be injected subcutaneously at the same time. All measures implemented are noted on the victim's appropriate medical card. He should be evacuated in seated position to a specialized traumatological hospital.

To refine the diagnosis, the victim's examination must be supplemented with roentgenological analysis. Anteroposterior and lateral X-rays are taken. The choice of treatment depends not only on the nature of the fracture but also on the victim's general condition. Skeletal traction or intraosteal osteosynthesis with a metallic rod are the most frequent forms of treatment, a hip cast being rarer.

When group II-IV compound fractures occur, the wound is subjected to initial surgical treatment.

Skeletal traction: After injection of 20 ml 1-2 percent novocaine solution at the place of fracture, the bone is placed in a standard cradle outfitted with blocks and pulleys. A pin may be passed through the femoral condyles or through the tibial tuberosity. A weight of 8-12 kg is used for traction (Figure 28). In most cases the fragments move to their correct positions in 1-2 days of traction. It is only in some cases, especially with initial fractures, that an attempt should be made to reposition fragments manually without removing traction, and preferably 2 hours after its application. If repositioning of the fragments is successful, the weight is immediately reduced to 5-7 kg.

Traction is applied with the femur abducted in the presence of subtrochanteric fractures and fractures of the upper and middle third of the diaphysis, since the central fragment is turned outward. The higher the level of fracture of the femoral diaphysis, the more the limb must be abducted on the traction cradle.

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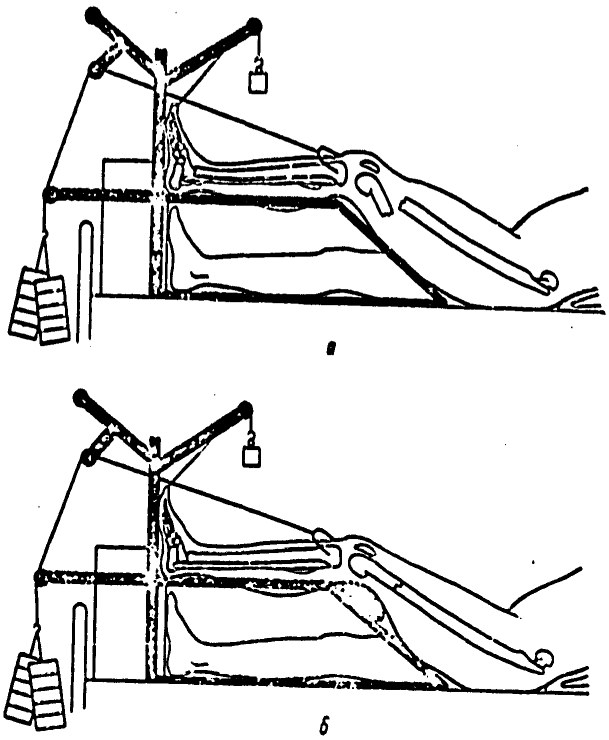

Figure 28. Traction for a Fracture in the Lower Third of the Femur: *a*--Peripheral fragment turned rearward; *b*--cylindrical cushion is placed beneath peripheral fragment, owing to which fragment turns forward.

The distal fragment of epicondylic fractures and fractures of the lower third of the femoral diaphysis is brought forward by placing a firm cylinder (sandbag) 5-6 cm thick beneath the lower fragment. The traction cord must pass a little below the axis of the femur. When fractures occur in the lower half of the femoral diaphysis, use of a cradle and traction in abducted position should be avoided. One or two days after application of traction the position of the fragments is determined by roentgenological and clinical analysis: Decisions are made as to whether the direction of traction need be changed, whether to increase the weight, and so on. After it is made sure that the fragments have been repositioned, the weight is gradually reduced such that by the 15th day it is not more than 6-8 kg. By the 5th week the weight is reduced to 5-6 kg.

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Therapeutic physical culture is prescribed beginning with the first days (movement of the foot, tension of femoral muscles, rhythmic movements of the kneecap).

A check X-ray should be taken 2-2.5 months after fracture. If the fracture is knitting, traction is removed. When traction is removed too early, before the bone knits, the axis of the femur becomes twisted rearward, causing a deformity. The patient is permitted to walk about with two crutches 2.5-3 months after fracture, without placing his weight on the leg.

A hip cast is rarely used to treat fresh simple fractures of the femoral diaphysis, since even well repositioned fragments often move within the cast. Usually skeletal traction has to be substituted by a hip cast when inflammatory phenomena occur in the area of the pin, when knitting is retarded, and so on.

Surgical treatment of fractures of the femoral diaphysis is indicated when soft tissues are interpositioned and when it is difficult to reposition and arrest the fracture. Surgery must be performed early (on the 2d-5th days).

Emergency surgery would be indicated when there is a danger of injuring or crushing vessels and nerves that had been displaced together with fragments, for example when there is pressure on vessels of the popliteal fossa in the presence of epicondylic femoral fractures, when there is pressure on the sciatic nerve, when subtrochanteric fractures occur, and so on. The intraosteal method for fixing bone fractures with a metallic rod has enjoyed the greatest acceptance (Figure 29).

Intraosteal insertion of a rod should be avoided when the upper and lower fragments of the femoral diaphysis are short as well as when cracks extend into the knee joint.

Additional immobilization with a plaster cast would not be required and the patient can be permitted to place his weight on the injured limb early when the indications are good for surgery and for intraosteal insertion of a metallic pin of appropriate thickness, length, shape, and quality, and when the upper and lower fragments are sufficiently long.

Usually the victims begin to walk with two crutches on the 10th-12th days, gradually increasing the weight carried by the injured limb. Therapeutic gymnastics should be started in the first days after the operation. The rod is removed only after the fracture knits. However, it cannot be removed earlier than 6 months after the operation.

Other forms of surgical treatment of fresh fractures of the femoral diaphysis (metallic plates, circular wiring, and so on) are used relatively rarely today. With all of these fixation methods, a dead-end cast is worn until the fragments knit.

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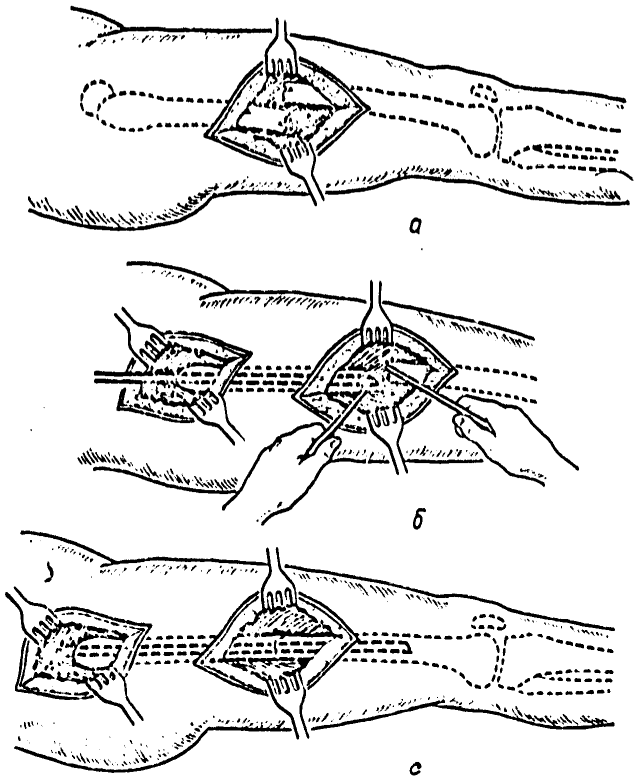

Figure 29. Surgical Method for Intraosteal Osteosynthesis of a Fracture of the Femoral Diaphysis: *a*--Incision at place of fracture, with fragments visible in wound; *b*--retrograde insertion of pin (from bottom upward) into proximal fragments; the incision is in the vicinity of the great trochanter; fragments are brought together with single-toothed hooks; *c*--rod inserted from central to peripheral fragment.

Fractures of the femoral diaphysis in children are usually treated by means of permanent cutaneous traction. Children up to 3 years of age are subjected to vertical traction (Shede's [Bryant's?] traction), with the injured leg raised and straight at the knee. Vertical traction is applied to both legs--the fractured one and the healthy one--if the child is restless. Knitting occurs by the 2d-3d weeks at this age. Horizontal adhesive extension can be employed with children from 3 to 5-6 years old; for this purpose the leg is kept straight at the knee and the coxofemoral joint.

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Children over 5-6 years old are treated for fractures of the femoral diaphysis by skeletal traction using a standard biplanar (Beler) splint. The pin is passed through the tibia, somewhat more distally than with adults--that is, 1-2 cm below the tibial tuberosity. A 6-8 kg weight is suspended from a cord tied to an arch secured to the pin. Skeletal traction is terminated after 3-4 weeks and substituted by adhesive extension of the thigh and shank for 2-3 weeks. A 3 kg pull is applied to the thigh, and 2 kg are applied to the shank. If there are no inflammatory phenomena in the area of the pin, skeletal traction may continue for up to 5-6 weeks. Restless children sometimes necessitate replacement of traction by a plaster cast.

Osteosynthesis with compressional-distractional apparatus is possible, using an Ilizarov apparatus with fractures of the femoral diaphysis and Volkov-Oganesyan apparatus with fractures of the lower third of the femur.

Fractures in the Vicinity of the Knee Joint

Fractures of the femoral condyles are treated as articular fractures. The plane of fracture when both condyles are injured is T- and Y-shaped. Moving into the popliteal fossa, bone fragments may crush or injure the popliteal artery. We distinguish between fractures of the inner and outer condyle, fracture of both condyles, and separation of a condyle. Fractures of the condyles may occur with and without displacement.

Symptoms: Pains are located in the knee joint and in the lower part of the thigh. The circumference of the thigh is larger in the vicinity of the condyles. The outlines of the knee joint are smoothed owing to hemarthrosis. Palpation of and pressure on the femoral condyles cause sharp pain. When the outer condyle is displaced upward the shank is in abducted position (genu valgum), while when the inner condyle shifts the shank is adducted inward (genu varum). Shortening of the limb occurs only with T- and Y-shaped fractures of the femoral condyles involving displacement. Passive movements in the knee joint are painful. The examination should end with palpation of vessels in the foot.

Detachment of the femoral epicondyle, to which a lateral ligament is attached, produces the same clinical pattern as rupture of the ligament.

Fractures of the patella usually occur due to direct trauma. Transverse fractures of the patella are encountered most frequently, while segmental, splintered, stellate, vertical, and other types of fractures are rarer. We distinguish between fractures with fragment separation and without fragment separation. Separation of fragments always indicates ruptures of the lateral ligaments of the kneecap (retinacula patellae). Owing to contraction of the quadriceps muscle the upper fragment of the kneecap is pulled upward, sometimes 4-6 cm and more. When the ligaments of the extensional apparatus remain whole, separation of fragments is impossible.

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Symptoms: Active movements in the knee joint and raising the straightened limb are impossible when fracture of the patella is coupled with separation of fragments. The knee joint is enlarged owing to hemoarthrosis. Palpation of the patella is painful. A gap can be felt when fragment separation occurs. The diagnosis is backed up with X-rays. A fracture can be seen especially well on a lateral X-ray.

Fractures of the tibial tuberosities are encountered predominantly among middle-aged and old people. Epiphysiolysis is observed among children. When fracture of the external tuberosity occurs, it is often simultaneously accompanied by a fracture beneath the head of the fibula, which may sometimes be complicated by injury to the fibularis nerve. We should distinguish between fracture of the internal or external tuberosity alone and fracture of both tuberosities of the tibia. Displacement may or may not accompany all of these fractures.

Symptoms: Swelling and a diffuse hematoma are present in the upper part of the shank when fracture of the tuberosities occurs. Hemarthrosis is noted in the knee joint. The outlines of the joint are smooth. The external tuberosity is displaced downward or if it undergoes compressional fracture, the shank deflects outward--genu valgum, while when the internal tuberosity undergoes the same type of displacement the shank deflects inward--genu varum. The area around the injured tuberosities is painful when pressed. Lateral mobility of the shank can be detected in the knee joint. Its function is impaired. When the fibularis nerve is injured the foot and toes are in the plantar flexion position.

When the spinous processes between the tibial tuberosities detaches, the anterior crucial ligament separates away together with the fragment. The degree of the process' displacement may vary. When the fragment is considerably displaced, the clinical pattern is similar to that of rupture of the anterior crucial ligament.

Detachment of the tubercle of the tibia is rare, and it occurs in response to abrupt and excessive contraction of the quadriceps muscle. The separated tubercle may shift upward; in this case flexion of the knee is sometimes impaired. This fracture, which usually takes the form of tubercular epiphysiolysis, is easily confused with osteochondropathy of the tubercle--Schlatter's disease, in the presence of which the altered tubercle is never displaced upward.

First medical aid and treatment: When bones in the vicinity of the knee joint are fractured, an immobilizing dressing must be applied. If the bone injures are more severe, the coxofemoral, knee, and ankle joints must immobilized. A hypodermic injection is given of 1 ml 1 percent or 2 percent promedol or omnopon solution, or 20 ml 1 percent or 2 percent novocaine solution at the place of fracture. When compound fractures are present, antibiotics, anatoxin, and tetanus serum must be administered simultaneously. All measures implemented are noted on the victim's appropriate medical card.

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Patients with injury to the knee joint must be conveyed to a traumatological-orthopedic or surgical therapeutic institution of the hospital base.

X-rays are taken of the joint in two planes during clinical examination.

When one or both femoral condyles are fractured and displacement does not occur, traction is applied with the leg almost completely straightened at the knee. For this purpose the traction is applied with a small weight on a cradle having one tilted plane for thigh and shank. Traction can be skeletal through the supramalleolar area, or subcutaneous, using the shank as the anchoring point. After 2-3 weeks, while still maintaining traction, movement is prescribed in the knee joint. Traction is removed 45 days after trauma. Sixty days after trauma the patient is permitted to walk, first without placing weight on the leg.

When fracture of one condyle is accompanied by displacement the upward-displaced internal femoral condyle is shifted downward by abducting the shank outward at the knee joint as far as it will go, while a displaced external condyle is forced downward by adducting the shank inward, after which a splint and hip cast are applied.

The procedure for abducting the head in the knee joint when the internal condyle is fractured, and for adducting the head in the presence of injury to the external condyle at the moment of application of the hip cast, as well as the subsequent treatment procedures are the same as for treatment of fractures of the tibial tuberosities involving displacement.

Treatment of these fractures may also consist of skeletal traction on a cradle with one tilted plane. The pin is inserted through the tibial tuberosity or through the supramalleolar area of this bone. A 3-4 kg weight is employed; lateral traction is simultaneously applied in the same direction as described above for bringing down the condyle in a single procedure.

Surgical treatment of fractures of the femoral condyle involving displacement is indicated when the femoral condyle cannot be set by the method described above, and when the remaining displacement could subsequently impair knee function. The operation would best be performed on the 3d-8th days after trauma (Figure 30). Pins, screws, or nuts and bolts are used in osteosynthesis. After the operation a plaster cast is applied for 4 weeks. Then therapeutic physical culture is prescribed. The patient is permitted to walk with his weight on the leg after 2.5-3 months. The fixing device is removed 4-5 months after the operation.

Treatment of fractures of both femoral condyles involving displacement entails bringing down both condyles to the same level, using skeletal traction with the tibial tuberosity as the anchoring point. Then the condyles are brought closer together by squeezing them together between both hands; they are secured in this position with a plaster sleeve applied to the knee. After 3-4 weeks the dressing is removed from the knee and active movement of the knee is started. Traction is removed after 2 months. The patient is permitted to walk with weight on the leg after 3-3.5 months.

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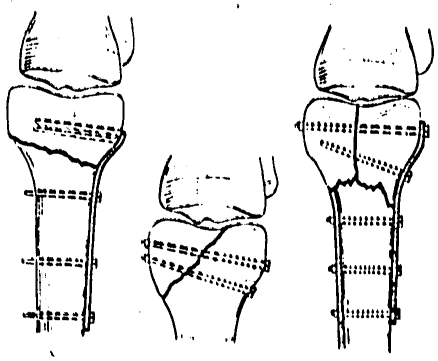

Figure 30. Osteosynthesis of a Condyle Fracture Involving Fragment Displacement.

If repositioning is unsuccessful, surgery is performed. After the fragments are set they are secured by a specially bent plate with screws and a bolt with a lock nut. Movement in the knee joint is prescribed beginning with the fourth week after the operation. The patient is permitted to walk with weight on the leg after 3-4 months.

Detachment of the femoral epicondyle: After blood is vacuumed away from the knee joint and 20 ml 2 percent novocaine solution are injected, a plaster sleeve is applied. The plaster cast must be shaped well to the limb. It is removed after 1.5 months. Therapeutic physical culture, massage, and physiotherapeutic treatments are subsequently prescribed. When the femoral epicondyle detaches together with the lateral ligament, surgery would be best. The operation is performed on the 2d-5th days after trauma. The epicondyle is sutured down with one or two knotted sutures, or it is secured to its seat with a screw. A plaster sleeve is applied for 3 weeks.

Fractures of the kneecap not involving separation of fragments and with separation within 2-3 mm are treated conservatively. The knee joint is punctured, and blood is sucked out. Twenty to forty milliliters of 0.25 percent novocaine solution are injected into the joint. Blood mixed with novocaine solution is sucked out. After this a plaster cast or splint is applied. The knee joint is slightly flexed (3-5°) immediately. The patient is permitted to walk about with a crutch or cane on the 7th-8th day. The plaster cast is removed 3-4 weeks after trauma. The plaster splint is removed from children in 2 weeks.

Fractures of the kneecap involving displacement of fragments are treated surgically. It would be best to operate immediately or 1-2 days after trauma. The operation is performed only in the absence of abrasions in the knee area, or after they heal. The main goal of the operation is to restore the ruptured ligament apparatus. Fragments are secured with a strong

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silk thread or stainless steel wire passed through the tendon of the rectus muscle and the patellar ligament itself, circularly around the patella. The torn lateral ligaments of the patella are sewn together with silk sutures (Figure 31). The knee is immobilized with a rear splint or plaster sleeve. After 4 weeks the plaster dressing is removed and therapeutic physical culture is prescribed. The plaster splint is removed from children 2-3 weeks after the operation.

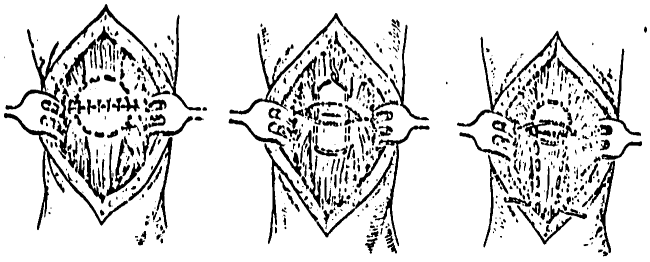

Figure 31. Suturing the Patella: *a*--Circular suture for a fractured patella, and the suturing of its lateral ligaments; *b*--suturing the patella with a U-suture passing through both fragments; *c*--restoration of patellar tendon after removal of the lower patella fragment using Kaplan's method; a channel is drilled beneath the tibial tuberosity, and a lavsan ribbon or thick thread is passed through it

When the patella is fractured such that one large upper fragment is displaced upward and the lower fragment is shattered, the latter is removed (partial patellectomy), and the tendon and lateral ligaments of the patella are sutured together. Complete removal of the patella (patellectomy) is performed with comminuted fractures involving displacement of fragments as well as when the upper fragment is shattered, especially among elderly and middle-aged people. When the tendon of the quadriceps muscle and the lateral ligaments are sutured together following removal of a shattered patella, movements in the knee joint are entirely satisfactory and painless. The negative aspect of this operation is that the anterior surfaces of the femoral condyles are unprotected and can be injured.

Fractures of one or both tibial tuberosities without displacement: Blood is removed from the knee joint, 20 ml 1-2 percent novocaine solution are injected into the joint, and a plaster cast is applied. On the 12th-20th day it is removed, and movements in the knee joint, massage, and paraffin therapy are started. In the 8th-10th week after trauma the patient is permitted to place weight on his leg, a little at first and more later.

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Treatment of fractures of one tuberosity involving displacement: When the internal tuberosity is fractured, as a result of downward movement of the fragment the knee assumes the varus position, while in response to fracture of the external tuberosity it assumes the valgus position. In order to raise the fragment upward, set both tuberosities at the same level, and restore the normal axis of the limb, when the internal tuberosity is fractured the shank is abducted outward at the knee with the help of lateral traction, and when the external tuberosity is fractured the shank is adducted. The pull must be smooth, and its force should be sufficient to pull the tuberosity upward. Thus the positions of the tuberosities become level and the varus or valgus position of the knee resulting from a displaced fracture of one tuberosity is corrected. A plaster cast is applied to the hip, shank, and foot without disturbing lateral traction on either side. In the fourth week the plaster cast is replaced and the limb is kept in its previous position so that the tuberosity would not move downward. The patient is permitted to walk with two crutches without placing weight on the limb. The plaster cast is removed 8 weeks after fracture, and a check X-ray is taken. Therapeutic physical culture is prescribed after removal of the plaster cast. The leg should not be allowed to bear the complete weight of the body before 3 months following injury. Displaced fractures of the tuberosities can also be treated by skeletal traction using lateral pull on a functional cradle or a uniplanar splint, or they can be treated by closed osteosynthesis using two facing pins supported by rests secured into an arch (Figure 32).

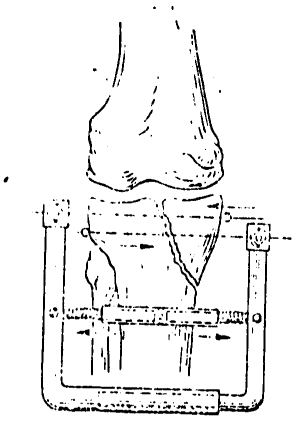

Figure 32. Closed Osteosynthesis of Fractures of Tibial Tuberosities Using Two Facing Pins Held by Rests Secured into an Arch.

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Treatment of fractures of both tibial tuberosities involving displacement: Blood is drained from the knee joint through a puncture hole, and 20 ml 1-2 percent novocaine solution are injected into the joint. The leg, straight at the knee, is placed on a cradle with one tilted surface for the thigh and shank (Figure 33). Traction is provided on the cradle with a pin passed through the supramalleolar area of the tibia or through the calcaneus. A 7-9 kg weight is hung from the arch. A check X-ray is taken 2-3 days later. Usually by this time the diaphysis of the tibia has been lowered by traction but the tuberosities continue to be apart. After this, pressure is applied to the tuberosities with both palms and a special screw vise to bring them together, and a plaster sleeve is applied without removing traction. The weight is gradually decreased to 5-7 kg by the 15th day and down to 4-5 kg by the 30th. Therapeutic physical culture is prescribed beginning with the first days. After 7-8 weeks, traction and the plaster sleeve are removed. Movement in the knee joint, massage, paraffin therapy, and mudbath treatment or mineral wax treatment are prescribed. The patient is permitted to walk with two crutches 2.5 months after injury, first without placing weight on the injured limb, and then with slight weight, gradually increasing it as time goes by.

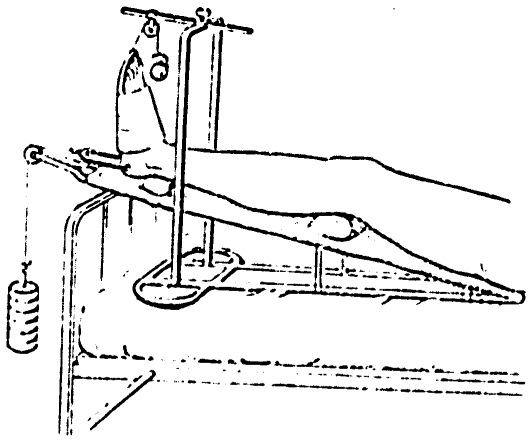

Figure 33. Skeletal Traction Using the Calcaneus as the Anchoring Point for Fractures of Both Tibial Tuberosities: Almost completely straight at the knee, the limb is placed on a Kaplan splint. Cylinders are placed beneath the knee and the Achilles tendon.

Surgical treatment of fractures of tibial tuberosities is indicated when the tuberosities cannot be repositioned correctly by the techniques described above; surgery should be performed in the first few days after trauma.

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Detachment of the spinous process of the tibia without displacement or with significant displacement: Blood is aspirated from the knee joint and a plaster (tutor) is applied with the limb straightened. When separations are coupled with displacement, surgery is indicated to secure the fragment and the anterior crucial ligament at their place of detachment.

Detachment of the tibial tuberosity involving displacement is treated surgically. Together with the ligament attached to it, the fragment is secured to the place of detachment from the tibia with a screw.

Fractures of Shank Bones

Fractures of the diaphysis of the shank bones: Fractures are observed most often as a result of an indirect force. For example, a skier making a sharp turn with the body and falling with the foot fixed in place can suffer a spiral fracture. Shank bone fractures are often compound. Fractures are usually observed in the middle and lower thirds.

We distinguish between diaphyseal fractures of just the tibia or fibula and fractures of both shank bones, with and without displacement of fragments.

In addition to the usual fractures, children often experience subperiostal fractures of the tibia. Various degrees of tibial epiphysiolysis, often coupled with triangular detachment of the back margin of the metaphysis, are observed in older children. Concurrently with displaced epiphysiolysis the fibula breaks above the external malleolus. Displacement accompanying epiphysiolysis is forward and outward.

Symptoms: The shank is deformed in the area of fracture. Its axis is distorted. The peripheral fragment is usually turned outward due to the weight of the foot. Shortening is within 1-3 cm in most cases. Pressing forward, the sharp end of the central fragment can easily pierce the skin or elicit its necrosis in this area. Abnormal mobility and crepitation are observed at the place of fracture. When shank bones are fractured the fibula breaks higher than the tibia, breaking lower more rarely. When the fibula remains whole, displacement of fragments of the tibia are observed. Patients can raise the leg but they cannot place weight on it.

An isolated fracture of the fibula is frequently unidentified, especially when it occurs in the upper and middle divisions, in view of the large mass of muscles present in this area. Palpation of the fibula at the place of fracture causes pain. When the fracture occurs in the area of the fibular head, special attention should be turned to movement of the toes and foot, since such movement frequently injures the fibularis nerve.

First medical aid and treatment: An immobilizing dressing made of boards or a Cramer splint is applied from the middle of the thigh to the shank, which must be arrested at the ankle joint. The victim is sent to the OPM,

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where immobilization is improved as necessary and then a subcutaneous injection is given of 1 ml 1-2 percent promedol solution or 20 ml 1-2 percent novocaine solution at the place of fracture. With compound fractures it would be suitable to administer antibiotics, anatoxin, and tetanus serum. All measures implemented are noted on the victim's appropriate medical card. In the specialized hospital, after clinical examination X-rays are taken in two planes--anteroposterior and lateral.

Fractures of the diaphysis of the tibia not involving displacement are treated with an unpadded plaster cast covering the foot, shank, and half of the thigh. When transverse fractures are involved, after 8-10 days a stirrup is put on and the patient is permitted to walk about with two crutches; on the 20th day the victim can walk with one crutch and a cane. The stirrup is put on on the 25th-30th day when the fracture of the tibia is oblique, spiral, or splintered and displacement is not involved. To avoid secondary displacement of fragments within the plaster cast, first the victim must walk around with two crutches, placing a slight load on the limb. The amount of weight placed on the injured limb is gradually increased.

When fractures of the diaphysis of the tibia involve displacement, skeletal traction on a standard cradle is employed. The pin is passed through the calcaneus or through the supramalleolar area of the tibula. A 6-7 kg weight is suspended from the arch. A check X-ray is taken 2-3 days later. If the fragments have repositioned themselves, beginning on the 8th-10th day the weight is gradually decreased, dropping to 4-6 kg by the 10th day. Traction is removed and a plaster cast reaching to the middle of the thigh is applied on the 25th day. A stirrup is plastered on and the patient is permitted to walk after 2 days, first with two crutches. The plaster cast is removed 8-12 weeks after trauma.

When fractures of the lower half of the fibula occur a plaster cast reaching to the knee is applied. A stirrup is plastered on after 2 days. On the 3d-4th day the patient is permitted to walk without crutches, placing his weight on his leg. The plaster cast is removed after 2-3 weeks. When the fibula breaks in its middle and upper thirds a plaster (tutor) is applied for 2-3 weeks. The patient is permitted to walk about without a cane on the 2d-3d day, placing his full weight on the leg. After the cast is removed, physical culture and physiotherapy are prescribed.

Transverse fractures of both shank bones not involving displacement are treated with an unpadded plaster cast reaching up to the middle of the thigh. On the 11th-12th day a stirrup is plastered on. On the 20th-25th day the patient is permitted to walk with two crutches, first without placing weight on the injured leg and later with weight on the leg.

Oblique, spiral, and splintered fractures of both shank bones not involving displacement are treated by skeletal traction on a standard cradle, since despite immobilization, secondary displacements would occur when such fractures are treated with a plaster cast. A 4-5 kg weight is suspended from

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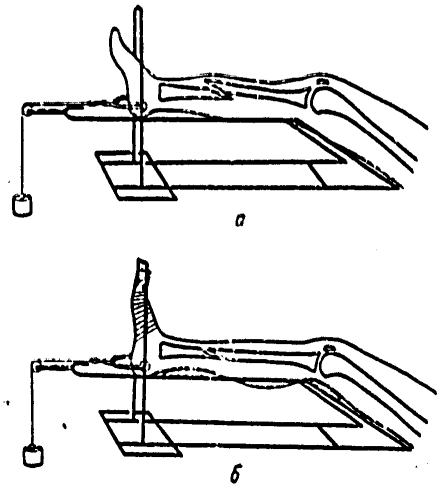

Figure 34. Skeletal Traction of a Shank Fracture Using a Standard Cradle (Beler's Method): *а*--Incorrect position of fragments; splint had been too tight in the area of the gastrocnemius muscle, owing to which the upper fragment of the tibia is displaced by gastrocnemius muscles and may pierce the skin; there is no cotton gauze pad beneath the Achilles tendon, and the foot is not suspended; *б*--correct position of leg for treatment of a shank fracture by skeletal traction; a pad is placed in the popliteal fossa, the splint is wound loosely beneath the gastrocnemius muscle, a pad is placed beneath the Achilles tendon, and the anterior part of the foot is raised. Fragments reposition well.

the arch. On the 20th-30th day, after some knitting of fragments has occurred, a plaster cast reaching to the middle of the thigh is applied. A stirrup is plastered on a day later. On the 27th-30th day the patient is permitted to walk with crutches. The plaster cast is removed 2-2.5 months after trauma. Therapeutic physical culture , massage, and physiotherapy are prescribed.

Fractures of the diaphysis of both shank bones involving displacement are treated by traction on a standard cradle. Traction is applied immediately after the victim arrives. The pin is passed through the calcaneus, and sometimes through the supramalleolar area (Figure 34). A 7-9 kg weight is suspended from the arch. A check X-ray is taken after 203 days. If the fragments have repositioned themselves, the weight is gradually reduced,

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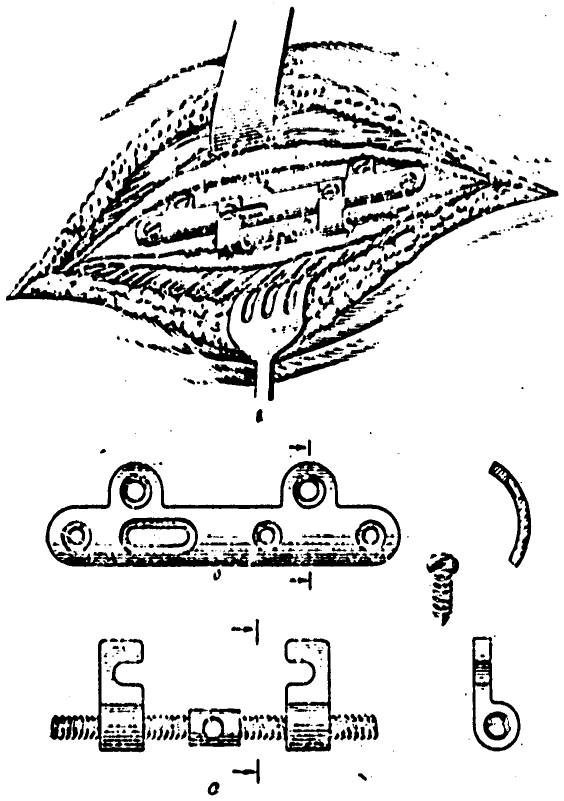

Figure 35. Osteosynthesis Using a Compressional-Detorsional Plate with Removable Appositioning Device Designed by Kaplan and Antonov: *a*--Overall view; *b*--compressional-detorsional plate; *c*--removable screw-tightened appositioning device.

dropping to 5-7 kg by the 15th day. A valgus position can be corrected with lateral traction on the outer side. To avoid overstressing, as soon as fragments of a transverse fracture are repositioned the weight is reduced to 5-6 kg. Traction is ceased and a plaster cast reaching to the middle of the thigh is applied on the 25th-30th day. When applying the cast, the possibility of twisting the shank axis must be prevented (rearward and outward twisting is noted most often). A stirrup is plastered on 2 days later. The cast is removed 2.5-3 months after trauma.

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Figure 36. X-Ray. Transverse Tibial Fracture. Osteosynthesis with a Kaplan- Antonov Detorsional-Compressional Plate: *a*--Before surgery; *b*--after surgery.

Figure 37. X-Ray. Spiral Fracture of Shank Bones. Osteosynthesis Using Two Screws: *a*--Before Surgery; *b*--after surgery.

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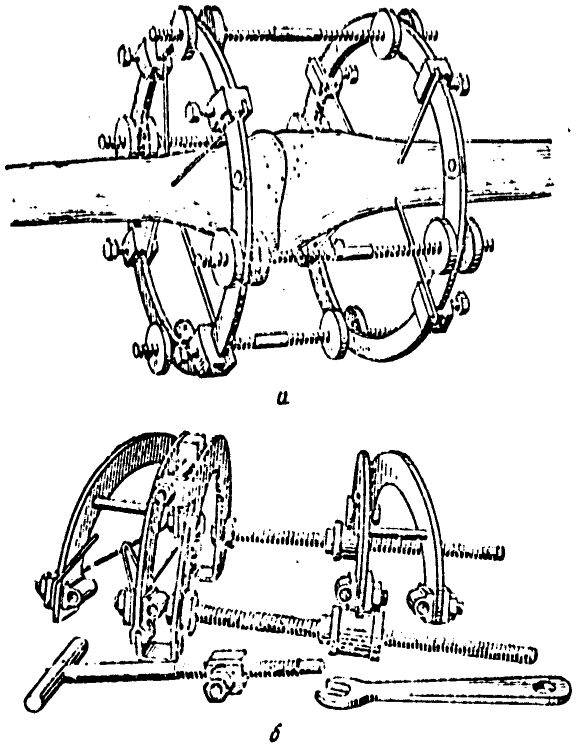

Figure 38. Ilizarov Compressional-Distractional Apparatus (*a*) and Gudushauri Compressional-Distractional Apparatus (*b*).

When the fracture is unstable, when soft tissues are interposed, and if repositioning of fragments by the methods above was unsuccessful, surgical correction and osteosynthesis with a Kaplan-Antonov compressional-detorsional plate and screws would be indicated in the very first days (Figures 35, 36, 37). When compound fractures of the shank bones are infected, compressional apparatus (Figure 38) and, more rarely, pins (Figure 39) should be employed.

A plaster splint is secured with soft bandage to children suffering subperiostal fractures and fractures not involving displacement. The dressing is removed after 4-6 weeks. When displacement is present in older children, skeletal traction is also employed, using the calcaneus as the anchoring point. Traction is removed and a plaster cast is applied after 3 weeks.

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Figure 39. X-Ray. Spiral Fracture of Shank Bones. Osteosynthesis Using Two Pins Passed Throught the Skin in Surgical Repositioning: *a*--Before surgery; *b*--osteosynthesis using two pins; *c*--knitting after 4 months.

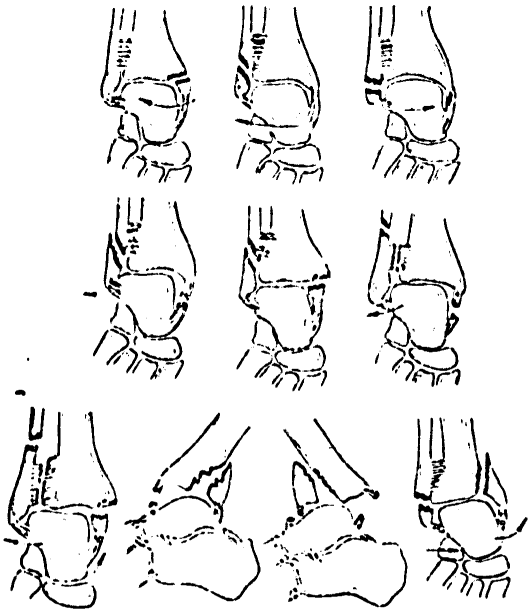

Figure 40. Diagram of Typical Malleolar Fractures

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Malleolar fractures are observed very often. In most cases they arise in response to direct trauma. Depending on the mechanism involved we distinguish between abductional-pronational, adductional, supinational, and rotational or eversional malleolar fractures (Figure 40). All malleolar fractures accompanied by displacement of the foot are classified as dislocation fractures.

From the clinical standpoint, trauma of the ankle joint is accompanied by isolated fractures of the external malleolus (this includes fractures of the fibula above the ankle joint) or the internal malleolus and fractures of both malleoli. These fractures may be combined with rupture of ligaments of the ankle joint and detachment of the outer margin of the tibia. In some cases displacement does not occur with such fractures, while in others displacement or dislocation of the foot outward or inward, separation of the fork of the ankle joint, and dislocation of the foot rearward or foreward may occur in connection with such complications.

Symptoms: Malleolar fractures not involving displacement of the foot are more difficult to diagnose than are fractures without foot displacement. The more significant the injury, the greater is the swelling and hematoma. Movement in the ankle joint is possible to a slight extent. When an abductional malleolar fracture occurs together with displacement, the foot is displaced outward from the axis of the shank.

Foot displacement is observed more rarely with adductional (supinational) malleolar fractures than with abductional fractures. The foot shifts inward, assuming the varus position. When malleolar fractures are accompanied by fracture of the rear margin of the tibia and displacement of the rear fragment upward, the foot not only shifts to the side by also assumes the plantar flexion position. In contrast to this, when the anterior margin of the tibia is fractured the foot assumes the dorsal flexion position.

First medical aid and treatment: A splint securing the ankle joint is applied (see Figure 55). The victim is sent to the OPM, and then he is evacuated to the hospital base for specialized traumatological aid.

X-Rays have especially great significance to correct diagnosis. In all cases x-rays must mandatorily be taken in two planes--anteroposterior and lateral.

When malleolar fractures do not involve displacement, following local anesthesia an unpadded plaster cast is applied as far as the knee, securing the foot at a right angle; this cast is worn for 6 weeks. On the 2d-3d day a stirrup is put on to permit walking.

When fractures involve displacement the fragments are repositioned, and then they are arrested in their correct position until they knit. Repositioning must be performed immediately after the victim arrives. Abductional (Dupuytren's) fractures are the most frequently encountered types of malleolar fractures involving displacement. They are characterized by subluxation of

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the foot outward. The place of fracture is anesthetized by injecting 20 ml 1-2 percent novocaine solution into the hematoma in the vicinity of the internal and external malleoli. Repositioning is performed as follows: The surgeon places one hand on the outer surface of the ankle joint and exerts a strong inward pressure; with the other hand he simultaneously grasps the shank on the inner side of the supramalleolar area and creates a counter-pressure. At this moment the physician can feel the bones set beneath his hands. After repositioning he shifts his hand from the supramalleolar area to the inner surface of the ankle joint, and then he compresses the fork of the joint with both hands to eliminate the gap in the interior tibiofibular articulation. If the internal malleolus is turned foreward, it is set with rearward pressure. Because the fragments can still shift after being set, the repositioned fragments should be secured with a V-shaped plaster splint bound to the limb with a gauze bandage. During the entire splint setting time the foot is kept at a right angle. After the V-shaped splint hardens the gauze bandage is cut along the anterior surface of the shank. An ordinary plaster cast is applied over the V-shaped plaster splint together with a rear splint reaching to the knee. The foot must be secured at a right angle in the ankle joint. Then check X-rays are taken. If repositioning was unsuccessful the bones are reset, using intraosteal anesthesia or general anesthesia, 5-6 days later, after swelling decreases. Swelling may increase after all of the manipulations, which would create the danger of crushing vessels and impairing limb circulation. In this case the plaster cast is cut apart. The plaster cast is replaced after 7-10 days. In all cases, 10 days after repositioning a check X-ray should be taken through the plaster cast, since repeat displacement may occur as swelling decreases. A walking stirrup is put on 15 days after fracture, after which the patient is permitted to walk about with crutches. The plaster cast is removed not earlier than 8-10 weeks after the fracture is set; a check X-ray is taken at this time. After the plaster cast is removed it is recommended that the patient wear a supinating device for 1 year; therapeutic physical culture and massage are indicated as a means for reducing swelling and restoring function more quickly. Tight bandaging of the ankle joint is recommended.

Inward subluxation of the foot occurs with adductional malleolar fractures involving displacement (Malgaigne luxations).

The fracture is set in the following way: The surgeon places one hand on the inner surface of the ankle joint and presses forcefully outward, simultaneously embracing the outer side of the supramalleolar area of the shank with the other hand, thus creating a counterpressure. At this moment the physician can feel the dislocated foot returning to its place beneath his hands, Then he lowers the hand located on the supramalleolar area down to the inner surface of the ankle joint and compresses the fork of the joint with both hands. After repositioning, the surgeon returns his hands to their former position. The method of anesthesia, the patient's position, the technique for applying the plaster cast, subsequent treatment and the recovery time are the same as with abductive fractures involving displacement of the foot.

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Single and double malleolar fractures involving detachment of the posterior inferior margin of the tibia: Such fractures are observed without fragment displacement and with rearward and upward dislocation of the foot mainly in combination with detachment of a small chunk of the posterior margin of the tibia, taking the form of a scale or a somewhat larger chunk. Such fractures are treated the same way as the single and double malleolar fractures.

When single and double malleolar fractures are accompanied by detachment of the inferior posterior margin of the tibia, in addition to outward or, what is much rarer, inward displacement of the foot, upward and backward displacement of the foot together with a triangular fragment is possible.

Repositioning is performed after anesthesia (Figure 41). First the surgeon grasps the back of the heel with one hand and presses it downward and forward; he places the other hand on the anterior surface of the shank, a little above the ankle joint, and pushes the shank back. Simultaneously the foot is maximally flexed dorsally at the knee joint. This brings the posterior margin of the fibula downward and corrects the foot's posterior dislocation. At this moment the surgeon can feel the foot's posterior dislocation correcting itself. Then the surgeon moves the hand that was grasping the heel to the outer surface of the ankle and applies a vigorous inward force; with his other hand he grasps the shank on its inner side in the supramalleolar area, creating a counterpressure. At this time he can feel the outward dislocation of the foot correct itself beneath his hands. After this the surgeon places both hands over the malleolar area and compresses the fork of the ankle joint. Simultaneously with this, the hematoma and edema are forced upward. After repositioning, the surgeon shifts one hand to the outer rear surface of the ankle joint, and with the other he grasps the shank's front inner surface in the supramalleolar area. This procedure prevents redisplacement of the foot backward and upward. During all these manipulations the patient's foot is severely flexed dorsally. This position should be secured with a combined V-shaped and circumferential plaster splint. When the cast is being put on, care should be taken not to displace the repositioned fracture. Anteroposterior and lateral X-rays should be taken immediately after repositioning and application of the cast. Attention should be turned to the line of the ankle. If the rear fragment remains in place and the foot's posterior dislocation has been corrected, the articular surface of the shank would be parallel to the curve of the articular surface of the astragalus. The cast is removed 1.5-3 months after fracture, at which time an elastic bandage is wound around the ankle joint. Wearing a supinating device for 1 year is recommended. Therapeutic physical culture, warm baths, and massage are prescribed.

Repositioning a fracture of the anterior inferior margin of the tibia involving upward displacement involves the following. With one hand the surgeon grasps the back of the shank above the ankle joint and presses forward; he places the other hand on the top of the foot and imparts maximum plantar flexion to it. If no other displacements had occurred, a plaster cast is applied with the foot in the plantar flexion position. After 2-3 weeks

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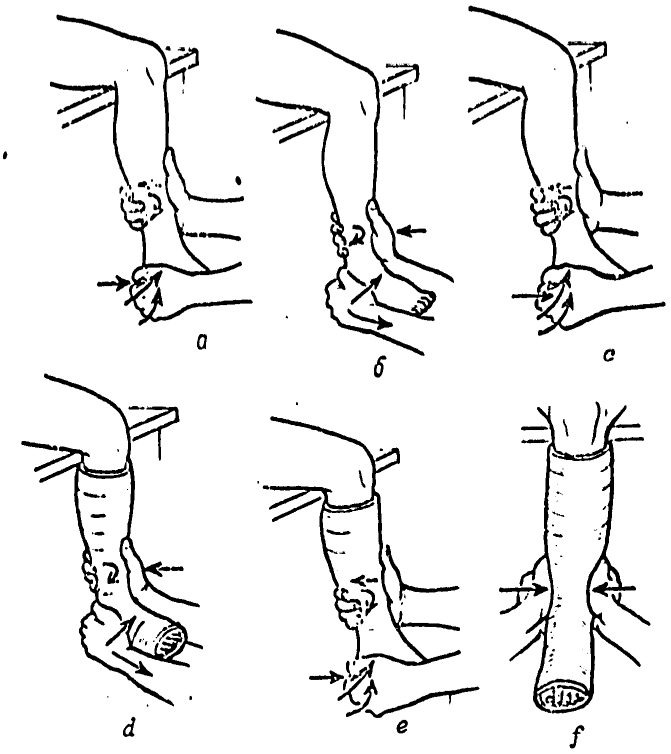

Figure 41. Procedure for Setting Fractures of Both Malleoli and the Posterior Margin of the Tibia Coupled with Rupture of the Ligament and Displacement of the Foot Backward and Outward, and for Applying the Plaster Cast: *a*--Repositioning stage 1; *b*--stage 2; *c*--stage 3; *d*, *e*, *f*--application of plaster cast.

the foot is carefully released from this position and placed at a right angle, after which it is secured with a plaster cast. Then a stirrup is applied. The patient is permitted to walk 3 weeks after fracture. The cast is removed after 2.5-3 months. Subsequent treatment is the same as with other fractures of the malleoli involving foot dislocations.

Surgical treatment of malleolar fractures is indicated when correct application of the repositioning technique fails to correct the foot's subluxation,

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to achieve correct appositioning of the fragments, and eliminate the gap between the two shank bones. It would be best to perform the surgery on the 2d-5th day after trauma. Edema and hematomas are not contraindications to surgery. The operation involves correcting the subluxation, eliminating the gap between the shank bones, and securing the displaced fragments in the correct position.

Fractures of Foot Bones

Fractures of the astragalus usually occur in response to excessive, violent dorsal flexion of the foot. This forces the neck of the astragalus into the inferior anterior margin of the fibula, causing it to split, forming two fragments corresponding to the body and head of the astragalus. Further force could cause complete posterior dislocation of the body of the astragalus. In addition to fractures of the neck of the astragalus, compressional fractures of the body of the astragalus occur. The mechanism of fracture involves falling on the foot.

Fractures of the astragalus are sometimes accompanied by fractures and dislocations of the navicular bone and other bones of the tarsus, as well as of the metatarsal bones.

Symptoms: Swelling is noted in the foot closer to the ankle joint and in the vicinity of the Achilles tendon. When the body of the astragalus dislocates rearward the foot assumes plantar flexion owing to the pull applied to the rear fragments by the Achilles tendon. A fragment can be felt behind the ankle joint beneath the Achilles tendon; the skin over it is stretched and pale. Development of dermal necrosis is possible, and sometimes the skin may rupture due to excessive stress. Movements in the ankle joint are sharply limited and painful. X-Rays taken in the anteroposterior and lateral projections have great significance to identification.

First medical aid and treatment: A Cramer splint securing the shank, ankle joint and foot is applied. The victim is sent to the OPM, and then he is evacuated to the hospital base.

Fractures of the astragalus not involving displacement: A plaster cast is applied as far as the knee, molding it carefully in the vicinity of the ankle joint and foot. The patient is permitted to walk without placing weight on the injured limb on the 7th day. After 5-6 weeks the plaster cast is removed, and physiotherapeutic treatments and the wearing of a supinating device when walking are prescribed.

When isolated fracture of the posterior tubercle occurs, a cast is applied for 2-3 weeks. Subsequent treatment is the same.

Fractures of the neck of the astragalus involving dorsal displacement of the foot are accompanied by dramatic flattening of the foot. Repositioning is performed under local or general anesthesia. Maximum plantar flexion is

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imparted to the foot, after which it is secured in a plaster cast that is well molded around the arch of the foot. The leg is placed on a cradle. When symptoms of impaired circulation arise, the cast must be cut apart. The cast is replaced after 3-4 weeks. The foot is cautiously moved from its position of plantar flexion to a right angle at the ankle joint. The plaster cast is meticulously molded in the vicinity of the arch. The cast is removed 2-3 months after trauma. A supinating device or an orthepedic shoe is worn for one year.

It is impossible to restore the bone in severe cases, when the body of the astragalus is completely crushed. A dead-end plaster cast is applied for 3-4 months.

If the body of the astragalus had rotated and dislocated rearward, skin sores and avascular aseptic necrosis of the body of the astragalus may arise. The bone can rarely be set without surgery. To avoid misfortune, immediate surgery must be performed to correct the dislocation of the astragalus. After the astragalus is repositioned a plaster cast is applied to the shank and foot in the same way as with fractures of the neck not involving rearward dislocation of the body of the astragalus. The patient is not permitted to place weight on the foot in the plaster cast for 3 months. Placing weight on the injured foot too soon would promote development of necrosis of the astragalus. The cast is removed after 4 months.

In most cases fractures of the calcaneus are associated with vertical falls on the heels. For this reason such fractures often occur on both feet. When the victim falls on his foot, the astragalus is forced against the calcaneus, splitting it into numerous fragments.

In addition to fractures of the body and anterior process of the calcaneus, accompanied by formation of numerous fragments, considerable deformation, and reduction of the angle of the articular part of the tubercle, we can observe fractures of the calcaneus without displacement of fragments, as well as marginal and isolated fractures of the calcaneal tubercle and process supporting the body of the astragalus.

Symptoms: The arch of the foot is flattened. The heel area is widened. The tips of the malleoli on the injured side are lower than on the healthy limb. The outlines of the ankle joint are smoothed, but movements are possible. Edema is noted in the vicinity of the Achilles tendon. Victims cannot place their weight on the foot due to pain in the heel.

Limited painfulness in the area of the heel corresponding to the place of injury is typical of marginal and isolated fractures of the calcaneus.

X-Ray analysis is especially valuable to identification. X-Rays of the calcaneus must be taken in the lateral and anteroposterior projections.

Treatment: Marginal fractures of the calcaneal tubercle, isolated fracture of the internal process of the calcaneus, which supports the body of the

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astragalus, and other fractures of the calcaneus not involving displacement are treated with an unpadded plaster cast applied as far as the knee. A walking stirrup is plastered on after 4-8 days. Walking is permitted 5-15 days after fracture. The cast is removed 3-6 weeks after trauma.

A fracture of the upper division of the calcaneal tubercle involving displacement (a so-called duckbill fracture) is repositioned under local anesthesia. Plantar flexion is imparted to the foot. At this moment the surgeon pushes out the hematoma, places both thumbs on either side of the Achilles tendon and presses downward on the fragment, which slips easily into its place. Then he applies a plaster cast reaching to the knee. The foot is secured in a slightly extended position (100°). The cast is removed after 5-6 weeks. Therapeutic gymnastics, massage, and physiotherapeutic treatments are then prescribed. If repositioning is unsuccessful, surgery is indicated 2-3 days after trauma.

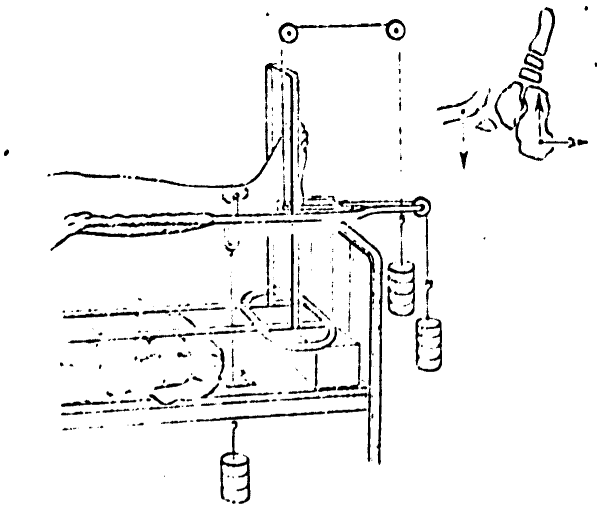

Figure 42. Kaplan's Triple Skeletal Traction for Old and Unstable Fractures of the Malleoli and the Posterior Margin of the Fibula Coupled with Rearward Subluxation of the Foot.

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When fractures of the calcaneus are accompanied by flattening, broadening, and shortening of the foot, skeletal traction with the pull acting in three directions is employed (Figure 42). A pin is passed through the calcaneus under anesthesia 2 cm back from the place where it is usually inserted for shank fractures. An arch is mounted on the pin. A second pin is passed through the supramalleolar area of the tibia to provide a counterpull, and a Kirschner's wire is attached to it. The leg is rested on a Beler cradle. A pull is exerted on the first arch along the axis of the shank with a 4-8 kg weight; hooks are mounted on the pin of the first arch on either side of the calcaneus, and a 2-4 kg weight, acting downward, perpendicular to the main axial pull, is suspended from these hooks. The cord is passed through a hole in the mattress and boxspring of the bed. A 2-4 kg weight is suspended from the second arch to provide an upward counterpull. On the 7th day the calcaneus is compressed with special forceps or by hand, and a circumferential splint is applied without removing traction. This traction is left in place with lower weight in each of the three directions (2-4 kg each). On the 30th-40th day the traction and the splint are removed; the latter is replaced by an ordinary plaster cast, which must be well molded, especially around the foot. The patient is permitted to walk with two crutches after 2-3 days without placing weight on his leg. The cast is removed 2.5 months after trauma.

In most cases fractures of the navicular bone occur as a result of a weight falling on the foot. Such fractures are usually accompanied by fractures of the cuboid and cuneiform bones.

Symptoms: Limited swelling and pain are noted in response to palpation of and pressure on the location of the navicular bone. When the detached fragment is dislocated dorsally a protruding bone can be felt in the swollen area. X-Ray analysis has great significance to identification of a fracture of the navicular bone.

Treatment: When dislocation occurs of the margin or the bony plate on the rear surface of the navicular bone a plaster cast is applied for 2-3 weeks. When separation occurs of the tuberosity of the navicular bone, to which the tendon of the posterior tibialis muscle attaches, a plaster cast is applied to the foot and shank in adducted and pronated position for 6 weeks to avoid flat footedness. In cases where the tuberosity has become displaced, surgical fixation of the fragment with silk sutures is indicated.

When fractures of the navicular bone are combined with fracture of the cuboid and cuneiform bones, a plaster cast is applied to the foot and shank for 6-8 weeks. Fractures of the navicular bone involving dorsal dislocation of the fragment should be set surgically. It is not recommended that the fragment be removed, since this would consequently lead to traumatic flat footedness and deformation of the foot. After the fragment is repositioned, a plaster cast is applied to the shank and foot for 10 weeks. As a result of such treatment, the navicular bone grows together with the astragalus and cuneiform bones. The functional result is good. The wearing of a supinating device is prescribed for 1 year after the removal of the cast.

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Fractures of the cuboid and cuneiform bones occur as a result of an object falling on the top of the foot. We distinguish between isolated fractures of these bones and fractures combined with fractures and dislocations of the tarsus and metatarsus.

Symptoms: Limited swelling and pain to the touch are usually present.

Treatment: Fractures of the cuboid and cuneiform bones are treated with an unpadded plaster cast applied to the foot and shank and molded well about the arch. After this the leg is elevated on a cradle. Walking is permitted on the 3d day. The cast is removed after 4-6 weeks. A supinating device is worn after this for a year.

Dislocations in the tarsometatarsal joint are encountered rarely and in most cases they are combined with fractures. A distinction is made of complete dislocation (involving all metatarsal bones) in Lisfranc's joint, which as a rule occur together with fracture of one or several metatarsal bones. Dislocations and fractures of other metatarsal bones often occur. Isolated dislocation is observed predominantly in relation to the first metatarsal bone. Dislocations of the metatarsal bones may be upward, downward, outward, inward, and in different directions (diverging dislocation). In most cases the displacement occurs upward and outward. A refined diagnosis is made on the basis of X-rays.

Treatment: Dislocations are corrected under general or intraosteal anesthesia. Repositioning is achieved with a pull on the distal end of the foot and direct pressure on the displaced metatarsal bones. After repositioning, a plaster cast is applied to the foot and shank for 4-8 weeks. After the cast is removed the patient wears a supinating device for 6-12 months.

If repositioning is unsuccessful, immediate surgery is indicated.

Fractures of the metatarsal bones arise mainly as a result of the direct effect of the force of an object falling on the foot, or of having a wheel running over and crushing the foot. In most cases this causes multiple fractures often combined with fractures of tarsal bones. We distinguish between singular and multiple fractures of the base, diaphysis (shank), neck (the diaphysis immediately below the head), and the head of metatarsal bones. Fractures of the base are often accompanied by fracture of tarsal bones. Fractures of the diaphysis of the metatarsal bones are usually transverse and oblique. Fragments resulting from such fractures often undergo displacement. Fractures of the heads of metatarsal bones often combine with comminution of the first row of phallanges.

Symptoms: Fractures of the metatarsal bones are typified by greater or lesser edema of the foot and pain in response to palpation of the sole and top of the foot. Pulling on the toe or pressure on the longitudinal axis of the metatarsal bone elicits pain in the area of the metatarsal bone's fracture. The diagnosis must be refined with X-rays. Detachment of the tuberosity of

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the first metatarsal bone should be differentiated from an accessory bone and, in children, from a projection of the epyphyseal line on the X-ray.

Treatment: When fractures of the metatarsal bones do not involve displacement, an unpadded plaster cast is applied to the shank, well molded around the foot. A walking stirrup is applied 2 days later. Walking is permitted on the third day. When just one metatarsal bone is fractured the cast is removed after 2-3 weeks, while when there are multiple fractures the cast is removed after 5-6 weeks. A supinating device should be worn for 6-12 months after this.

Fractures involving displacement of fragments must be set. It should be remembered that growing edema and a hematoma may cause development of dermal necrosis on the back of the foot. Immediate setting of fragments and immobilization have great significance to preventing these complications. When fractures occur of the metatarsals and the phallanges and displacement occurs, local or intraosteal anesthesia is employed. A plaster cast is applied to the foot and shank, and a metallic traction frame is secured to the foot opposite the toes. A thin pin, the ends of which are secured to a small arch, is passed through the ungual phallanx of the appropriate toes. Then repositioning is achieved by traction applied to the appropriate toe. When fragments are displaced toward the top or sole of the foot, pressure is simultaneously applied to the displaced fragment, in the opposite direction. An arch attached to a pin passed through the ungual phallanx is tied to the metallic frame by means of a communicating rubber tube. A day later a check X-ray is taken. If repositioning is incomplete, the rubber bands are tightened even more. Traction is removed after 3 weeks, and a walking stirrup is applied. The plaster cast is removed in 1 month when just one bone is fractured, and 6-8 weeks when several metatarsal bones are fractured. A supinating device is worn for 1 year. If a check X-ray taken 1-2 days after fracture of the diaphysis of a metatarsal bone shows that repositioning has been unsuccessful and that displacement of the metatarsal bone would encumber walking later, surgical intervention is indicated. Causes of unsuccessful repositioning by traction include, as a rule, impaction of the ends of the fragment into interosteal tissues, and interpositioning of muscles. A thin pin is passed through each metatarsal bone to keep the fragments in place.

The pin is removed after 6-8 weeks. A plaster cast is applied after the operation. Subsequent treatment is the same as with fractures of metatarsal bones treated without surgery.

Fractures of the toes are encountered when objects fall on the foot and when the toes are crushed. Simple fractures of the second row of phallanges and of the ungual phallanges do not as a rule subsequently produce any functional impairments. Fractures of the first row of phallanges, especially of the big toe, require exceptional attention since in the presence of ankylosis and stiffness in the metatarsophallangeal joint it becomes difficult to move the leg from the ground, and the victim constantly feels pain when walking.

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Symptoms: Swelling and pain to the touch and pressure are noted in the area of the fracture. Pressure on the longitudinal axis of the toe and pulling it cause pain in the vicinity of the fracture. The diagnosis is refined with an X-ray.

Treatment: When simple fractures of the toes occur without displacement, several layers of adhesive tape are wound around the appropriate toe for 10-15 days.

Fractures of a phallanx in the first row coupled with displacement of fragments at an angle open in the dorsal direction, especially fractures of the first phallanx of the big toe, are treated by traction applied to the tip of the toe. Traction is removed after 3 weeks, and a walking stirrup is plastered on. The cast is removed after 2-3 weeks.

If stiffness and deforming arthrosis of the metatarsophallangeal joint develop after knitting of a fracture of the first phallanx of the big toe, and in some cases of the second and third toes, causing pain and hindering walking, resection of the base of the first phallanx is indicated.

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CHAPTER 7

INJURIES TO MAJOR BLOOD VESSELS AND PERIPHERAL NERVES

Vessel Injuries

In World War I, vessel wounds made up 0.8 percent of all wounds in areas of army operations (N. N. Burdenko) and 1.2 percent in rear hospitals (V. E. Salishchev); they made up 1 percent of all wounds in the battles of Lake Khasan (M. N. Akhutin), and in the Great Patriotic War they made up 1.2 percent in the troop and army sectors (V. I. Struchkov) and 2.3 percent in the frontal sector (B. V. Petrovskiy).

Petrovskiy suggested the most complete classification of gunshot wounds in relation to the type of vessel injured and the clinical nature of the wound (1945-1955):

1. Arterial wound:
   a) Without initial hemorrhaging and a pulsating hematoma (vascular thrombosis);
   b) accompanied by initial arterial hemorrhaging;
   c) coupled with formation of a pulsating arterial hematoma (aneurysm).
2. Venous wound:
   a) Without initial hemorrhaging and hematoma (vascular thrombosis);
   b) accompanied by initial venous hemorrhaging;
   c) coupled with formation of a venous hematoma.
3. Arterial wound combined with venous wound:
   a) Without initial hemorrhaging and a pulsating hematoma (vascular thrombosis);
   b) accompanied by initial arteriovenous (mixed) hemorrhaging;
   c) coupled with formation of a pulsating arteriovenous hematoma (aneurysm).

Traumatic injuries to arteries and veins elicit various changes in the vascular wall, disturbing normal hemodynamics. The degree and characteristics of these changes depend on the nature of vascular injury, on the causes eliciting trauma,

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and on the severity of the latter both at the place of the wound and in the zone of action of the wounding object and the shock wave.

Trauma to major blood vessels of the limbs is often extremely diverse. It depends on very many causes. In a number of cases a vessel may be injured when the wound channel is located away from the vessel and it does not directly disturb its integrity. Contusions of the vessels and their indirect injuries are often encountered in the clinical practice of a military field surgeon.

The margins of an arterial wound may be smooth and untorn, if the wounding missile was smooth (for example a bullet piercing soft tissues at a right angle). A deformed bullet or sharp fragments from various missiles, especially if they wound a vessel at an acute angle, may elicit significant anatomical destruction over a great area. In this case the walls of the blood vessel delaminate, rupture, and flex inward or outward--that is, they exhibit the most diverse forms and degrees of injury. In some cases rupture occurs in the muscular and endothelial coats while the tunica adventitia remains whole. In this case the elastic pull of the smooth musculature of a medium-sized artery could elicit significant diastasis of the vessel's middle and internal coats, with the external coat remaining whole. In these cases internal bleeding (in the intermuscular space) and external bleeding are more significant than with complete rupture of the artery, where twisting of delaminated intima and adventitia may not only reduce blood loss but also cause rather prolonged hemostasis due to formation of a large thrombus at this point.

Sometimes the injured artery is deep within tissues in the presence of a nongaping wound. Blood from such a vessel does not drain out of the body, thus promoting arisal of a pulsating hematoma. Later it transforms into a traumatic aneurysm.

The most frequently encountered clinical symptom of wounding of a major blood vessel is external bleeding, which is noted in 45-56 percent of the cases of combat trauma. Other signs of injury to a major vessel--weakening or disappearance of pulse distal to the wound, local dermal cyanosis, pallor and cooling of the limb, and reduction of active finger movements--are noted by physicians much more rarely in the first stages of evacuation.

The general appearance of a wound victim who has lost much blood is typical. He is pale and covered with a cold sweat, his breathing is frequent and shallow, and he answers questions quietly, with difficulty, periodically losing consciousness. A weak frequent pulse completes the picture of acute blood loss.

The general principles of treating wounds of the blood vessels boil down to the following: Temporary stoppage of bleeding at the place of trauma, final stoppage of bleeding during surgical treatment of the wound (ligation of the bleeding vessel or application of a vascular suture to the wounded arterial wall), replacement of lost blood, and prevention of wound infection.

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In the stage of first physician's aid, it is important for the physician to check the manner in which a tourniquet is applied. Sometimes the tourniquet is too tight, which intensifies pain. In other cases a loose tourniquet may even promote greater blood loss by creating congestional plethora in the limb. A tourniquet must not be left on for more than 2 hours. After this time the tourniquet should be removed for a few minutes, compensating its action by applying pressure to the major vessel with the finger proximal to the wound. During the cold part of the year the time the tourniquet remains on should be reduced to 1 hour. Application of a ligature to a vessel within a wound is the most frequently employed method of final stoppage of bleeding.

First the wound is subjected to initial surgical treatment. It would be better for a surgeon with little experience to perform the first part of the operation with the tourniquet on. Injured, dirty, and unviable soft tissues (cellular tissue, muscle) are carefully excised, mandatorily preserving any large trunks. The skin must be treated extremely conservatively. After dirty tissues are removed the surgical instruments are replaced and the tourniquet is removed. Sometimes a large bleeding artery contracts so much that significant diastasis of its proximal and distal fragments occurs. The skin-and-muscle wound should be broadly dissected along the path of the limb's major blood vessels in order to facilitate discovery of their location. It is only in this way that the bleeding vessel could be found. Vishnevskiy and Shrayber advise resecting the traumatized portion of a vessel at the time of its ligation in anticipation of the possible development of a purulent complication. In their opinion infiltration of the vascular sheaths with a 0.25 percent novocaine solution would be useful in eliminating spasms in the branches of the ligated vessel.

Irrespective of the sort of anesthesia that will be employed (local or general), it would be extremely useful to perform a (futlyarnyy) blockade of muscles of the shoulder (100-150 ml 0.25 percent novocaine solution) or the thigh (150-200 ml) prior to surgery. When trauma occurs to vessels of the pectoral or pelvic girdle, a vagosympathetic novocaine blockade should be performed in the first case (20 ml) and a paranephral blockade should be performed in the second (80 ml).

As with arteries, wounds of major veins require ligation of both ends of the vessel. It would be desirable but not mandatory to apply a lateral suture with an atraumatic needle using synthetic thread over an injured but not completely cut vessel wall.

When the number of casualties is small, plastic surgery can be performed on arteries, an autovenous or alloprosthetic procedure being best. Venous autoplasty (where the graft is taken from the great saphenous vein) produces satsifactory results in reconstruction of major limb arteries in contused and crushed wounds of any etiology, including gunshot wounds, as well as in the presence of developing reactive inflammatory alterations (Yu. V. Bazilevskaya). Because of the limited possibilities for procuring lyophilized arterial

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homotransplants, which have proven themselves in peacetime medical practice, they will not enjoy extensive use in wartime (N. I. Krakovskiy).

The injured major arteries of many casualties will be ligated only, even in the presence of a real threat of the limb's ischemia. Research by A. K. Revskoy has established that ligation of major limb arteries leads first to development of functional changes in muscle tissue and then to changes of greater severity, going as far as necrosis. Electron microscopy of muscle tissue established that mitochondria undergo swelling 4 hours after ligation, and disintegration after 24 hours.

Irreversible changes in muscle tissue are characterized by diffuseness of outline and of longitudinal and transverse striations, stasis of erythrocytes, thrombosis, and absence of glycogen in muscle fibers. Injection of 10 percent calcium pangamate, 0.12 percent hydrogen peroxide, 1 percent ATP solution, and 0.25 percent novocaine solution into the calcaneus of the ischemic limb in the first 5-6 hours, and combined administration of calcium pangamate intraosteally and oxygen subcutaneously would keep it viable for 3 days.

Intraosteal administration of low molecular weight dextran into a limb with ligated major arteries would prevent development of capillary thrombosis and promote maintenance of microcirculation in ischemic tissues (A. K. Revskoy).

Sometimes what appears to be reliably stopped initial bleeding resumes after several days. The usual signs of the resumption of bleeding are the feeling of separation of tissues about the wound, intensification of fever, and change in color of purulent discharge, in which traces of fresh blood are noticed. Secondary, often profuse hemorrhaging arises more often at night. The dressing becomes copiously moistened with slowly coagulating blood. It is usually impossible to find the bleeding vessel upon inspection of the wound, going as far as dissection of granulating tissues.

Processing the wound with alcohol and subsequently packing it carefully, layer by layer, with gauze saturated with Vishnevskiy's ointment produces a positive therapeutic effect, though not always. Bleeding may recur. In the event that bleeding does recur, the major artery would have to be exposed by means of a separate incision away from the wound, and all of its branches that may have a relationship to the secondary bleeding would have to be ligated (ligation of the vessel along the length of the wound .

When extensive wounds are present on the buttocks, accompanied by injury to gluteal arteries, the internal iliac artery is ligated.

Surgeons treating jaw and face wounds must sometimes ligate the external carotid arteries.

Despite the fact that many surgeons (Yu. V. Bazilevskaya, Yu. V. Novikov) have been making broad use of arterial plastic surgery in infected wounds, this

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most sophisticated form of surgery may be performed only in the event that there are no clear signs of severe wound infection, or if the injured vessels could be covered over with adjacent soft tissues.

In cases where the limb remains viable after ligation of a major vessel, a pattern of progressive dystrophy may often develop several weeks later. The skin on the limb becomes dry, pale, and cold. Tropic ulcers often form on it, especially if a lower limb is injured. Skeletal musculature and subcutaneous cellular tissue undergo noticeable atrophy. A light physical load causes aching, making it necessary to keep the painful limb still. So-called disease of a ligated major limb artery develops. In these cases N. P. Ushakov, F. M. Plotkin, and others recommend preganglionic sympathectomy. But this operation is palliative, and it cannot completely normalize impaired limb circulation. N. I. Krakovskiy used a bypass. Success would be possible only on the condition that not more than 2 years had passed from the time a major limb artery had been ligated.

Diagnosis and Treatment of Pulsating Hematomas, Arteriovenous Fistulas, and Aneurysms

Pulsating hematomas, traumatic arteriovenous fistulas, and aneurysms are diagnosed on the basis of medical history data, the victim's complaints, and the results of clinical examination and laboratory and roentgenographic analyses.

Presence of indications of recent trauma in the medical history has important significance to differential diagnosis. Examination of the victim and comparison of the healthy and stricken limbs supplement the anamnestic information. Determination of a pulsating swelling in the projection of a major arterial vessel, for example on the sides of the neck or in the inguinal, papliteal, axillary, and brachial areas would confirm the suggested diagnosis. Injuries to deeply lying major arteries may not be recognized in the first examination. This pertains to trauma of vessels of the pelvis and of the gluteal and subclavian regions.

The following symptoms are typical of a forming pulsating hematoma: Presence of a pulsating swelling, noise determined by palpation or auscultation, weak pulse in major vessels distal to the swelling, pain in the swollen area, sometime irradiating along the course of the vascular trunk; cooling of the distal portion of the limb, cyanosis of the skin, edema, paresis, paresthesia, and anesthesia. Laboratory analyses (capillaroscopy, oscillometry, venotonometry, dermal thermometry, polarography, rheovasography) indicate disturbance of local arterial, venous, and capillary circulation.

Roentgenovasography has acquired the most practical significance in recent years. It permits us not only to establish a topical diagnosis most precisely but also to reveal the dimensions and length of the pulsating hematoma, arteriovenous fistula, or traumatic aneurysm (Figures 43 and 44).

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Figure 43. Arteriogram of an Aneurysm on the Brachial Artery

Figure 44. Arteriogram of an Aneurysm on the Femoral Artery

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In order that we can acquire a distinct vasographic picture of the forming aneurysmatic sac and especially collateral bleeding from it, we must consider the concentration of the contrast medium and its quantity depending on the dimensions of the aneurysm and its location. We would have to reckon specially with the general reaction of the casualty's body in our investigation of arteriovenous aneurysms and intervascular fistulas, at the time when contrast medium is entering the arterial or venous channel.

Forty to fifty milliliters of contrast medium--a 35-40 percent solution of diodone, gipak, or urografin--can be injected either through the arterial inlet or directly into the aneurysm. This is called aneurysmography. Sel'dinger's method is used to precisely determine the location and topography of aneurysms in the pectoral and pelvic girdles.

Before roentgenovasography and arterial plastic surgery were introduced into clinical practice, surgeons did not operate on new pulsating hematomas, waiting for the development of large collaterals which could provide sufficient blood to the stricken limb in the event that the main arterial channel is shut off.

Autovenous grafts (fragments of the large saphenous vein), lyophilized arterial homotransplants, and alloprosthetics made from synthetic fabric, braided, or woven materials are presently employed in arterial plastic surgery (Figure 45). This permits surgeons to operate on pulsating hematomas before development of an indirect blood supply.

Figure 45. Operation: After the aneurysm in the femoral artery is removed, circulation is restored in the limb by a corrugated synthetic vascular prosthesis.

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In autovenous plastic surgery the proximal end of the vein is sutured to the distal segment of the artery, while the distal end of the vein is sutured to the proximal segment of the artery. This is done so that the valves present in the veins would not create an insurmountable barrier to the flow of blood.

Autovenous plastic surgery can be employed to correct minor arterial defects (4-5 cm), on the mandatory condition that this portion of the vessel is located in the thick of muscle tissue. It should be remembered that the thin-walled vein fragments offer poor resistance to the pressure of blood circulating in a major artery. These vein fragments may later form into a venous aneurysm. This is also possible when the length of the venous auto-transplant is more than 5-6 cm.

When surgery is performed on vessels in connection with a pulsating hematoma, an aneurysm, or arteriovenous fistulas, the principles of maximally radical surgery must be followed--that is, the contents of the pulsating hematoma or aneurysmatic sac should be removed, and the walls of the sac should be excised or the arteriovenous fistula should be closed off, after which the venous and arterial portions of the fistula are ligated while preserving conduction in the main artery and vein.

Extensive arteriovenous aneurysms of the pelvic or pectoral girdle, where the risk of losing the patient on the operating table due to hemorrhagic shock is very great if an attempt is made to remove, at all costs, the entire aneurysmatic sac, fused with surrounding tissues and located deep within the pelvis or the subclavian region, are an exception. In these cases application of a bypass and disconnection of the aneurysmatic sac from the main artery and vein would be indicated.

Surgery on major vessels begins with isolation of the proximal and then the distal sections of the main limb vessels a significant distance from the aneurysmatic sac and, if possible, in unaltered tissues. The procedure for isolating the aneurysmatic sac may be relatively easy only when it is small, when it is located in superficial tissue layers, and when it is not surrounded by extensive scars caused by serious wounding and purulent inflammation. Gradually delaminating the scar tissue with a dull or sharp instrument, the surgeon creates a sufficient opening to expose the vascular inlets and outlets of the aneurysmatic sac. All collaterals are ligated to the extent possible. Rubber tourniquets or special clamps are applied to main arteries and veins. Veins must be separated from the scar site especially cautiously, patiently freeing their anterior, lateral, and posterior walls; injury to a large venous trunk in the presence of an arterovenous aneurysm elicits intense bleeding, which is sometimes not easy to stop. Sometimes as a result of this the entire venous trunk must be sacrificed, ligating it between hemostatic clamps after hasty cutting of the trunk, raising the clamp upward to the surface of the wound. It is only after this that the place of the vessel's rupture could be found.

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It would be useful to employ the following technique when seeking the place of injury to a large bleeding branch of a major artery: The surgical assistant injects a stream of physiological sodium chloride solution or a 0.25 percent novocaine solution into the place of bleeding under high pressure using a 10-20 gm syringe and a long, thin needle. The stream of water washes the blood away and facilitates the search for the bleeding area. This same technique could be used for hemostatic purposes in the presence of wounds to a large vessel. As a rule a hemostatic tourniquet is not applied to the limb prior to the operation. All stages of the operation can usually be performed without applying a tourniquet and without extensive blood loss. It would be better for a less-experienced surgeon to operate with a tourniquet on.

In cases where it is impossible for practical purposes to remove an aneurysm, after tourniquets are applied the aneurysmatic sac is not excised; instead, it is simply cut open to permit removal of blood clots and fibrin, and collaterals are ligated from within the sac.

Arterial plastic surgery should be performed in the presence of aneurysms in the subclavian, brachial, carotid, femoral, and popliteal arteries. Such surgery should not be performed in the presence of aneurysms in the arm, wrist, shank, foot, and buttocks.

Nerve Injuries

Nerve injuries are subdivided into closed and open. In the 20th century through World War II inclusively, open injuries resulting from gunshot wounds dominated. The percentage of casualties with nerve injuries fluctuated from 1.5 to 4 in relation to all wounded casualties and 10-20 in relation to just limb wounds alone. Today, because of the extremely higher level of the army's mechanization and use of weapons of tremendous explosive power, we would have to expect a sharp rise in the proportion of closed injuries resulting from tractional trauma of the limbs and compressions caused by collapsing buildings and shelters.

All forms of nerve injuries are brought together into two groups depending on morphology--1) anatomical breakage of the nerve trunk, complete or partial, and 2) injuries within the nerve trunk (hematomas, foreign bodies, breakage or crushing of nerve tracts).

The main sign of complete anatomical breakage is disturbance of the integrity of all fibers and sheaths making up the nerve trunk, and complete separation of central and peripheral segments in connection with this.

Injuries inside the nerve trunk are characterized by the fact that the outer epineurium may exhibit relatively little damage while changes in nerve tracts and connective tissue within the trunk are very serious and widespread.

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General symptoms and diagnosis of nerve injuries: Nerve injuries manifest themselves clinically as a pattern of complete or partial disturbance of conduction. The extent of this disturbance is determined from symptoms of lost movements, sensitivity, and autonomic functions in the areas supplied by all branches of the injured nerve below the point at which it is wounded (injured). In addition to signs of such losses, we may note symptoms of irritation taking the form of paresthesia and pains of varying intensity. Disturbance of conduction in the nerve trunk occurs at the moment of nerve injury.

Much time is not required to make a tentative diagnosis of nerve injury during the initial examination of the victim.

The medical history may be brief, but it is very important. Most wound victims suffering gunshot injury to nerves note that at the time they were wounded they experienced the feeling that the "limb had been torn off," that it was "struck by an electric current," and so on. Such sensations do not usually arise with incised wounds; the victims usually complain of loss of sensitivity in the corresponding zone. If a tourniquet had been applied, disturbances in movements and sensitivity may stem from both mechanical compression of nerves and ischemia.

Examination of the injured limb must precede investigation of movements and sensitivity. Some positions of the limbs are so typical that a hypothetical diagnosis begs itself literally from the first glance. In the presence of closed injuries of the entire brachial plexus and in the presence of upper paralyses the upper limb hangs lifelessly and is often rotated inward. When hemorrhaging occurs together with ruptures of cerebral membranes and liquorrhea, for example in the presence of intradural breakage of nerve roots leading from the cervical enlargement of the spinal cord and in the presence of fractures of the transverse processes of the cervical vertebrae, deformation of the subclavian region is immediately evident. Horner's syndrome, which is unfavorable in prognostic respects, can also be revealed by examination. Wounding of the radial nerve at the shoulder causes obvious presence of mild paralysis of muscles on the extensor side of the forearm coupled with a hanging wrist, partially bent fingers, and disappearance of the outlines of extensor tendons on the wrist. In precisely the same way, the outlines of extensor tendons disappear from the body of a hanging foot when breakage of the common peroneal nerve or the fibular portion of the sciatic nerve occurs. Partial straightening of the second and third fingers are typical of high breakages of the median nerve to the upper third of the forearm inclusively. When breakage of the median nerve occurs below the upper third of the forearm, disturbances in flexure of these fingers do not occur and motor disturbances are minimal due to the fact that branches to the flexor muscles had already originated above this point. An abducted position of the fifth finger is the most typical of a severed ulnar nerve, and the typical claw position of the fingers is not always noted in the acute period.

Palpation and percussion along the course of the nerve trunk level with the point of nerve injury is almost always accompanied by projected sensations

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in the vicinity of the terminal branches. Pains resulting from palpation and percussion over the place of injury often indicate presence of a foreign particle in the nerve. The portion of the nerve below the level of injury is painless as a rule in the first period after trauma in the presence of all forms of anatomical breakage.

Analysis of movements in the first hours and days following injury is usually difficult owing to pains in the vicinity of the wound, due to which victims avoid active movement. Because the same movements could be performed with different muscles, the attention must be turned in the investigation of motor disturbances not to movements in general but to the function of each muscle innervated by the given nerve.

To provide quick initial orientation, sensitivity is investigated with the help of the simplest techniques--stimulation by forceps, compression of the phalanges, and pin pricks. The investigation begins with the so-called autonomic zones. If sensitivity is impaired to the point of anesthesia in the autonomic zone, if incised and puncture wounds are present and a tourniquet had not been applied prior to this time, this sign is an extremely probable indication of complete anatomical breakage of the corresponding nerve. If a tourniquet had been applied, profound sensitivity impairment may persist for a long time without direct wounding of the nerve. Profound sensitivity impairments may last for 7-15 days in the presence of gunshot wounds as a result of concussion, in the absence of anatomical injury to the nerve.

The revealed sensitivity impairment should be noted in the medical documents to permit subsequent observation of the dynamics of any changes occurring. The autonomic zone of the median nerve, in which sensitivity impairments are always noted when this nerve trunk experiences anatomical injury, consists of the two last phalanges of the second finger. The autonomic zone of the ulnar nerve is the tip of the fifth finger. However, when wounds occur low down on the ulnar nerve, beneath the point at which its dorsal branch originates, it may contribute significantly to innervation of the fifth finger. In such cases sensitivity impairments accompanying breakage of the palmar branch would be limited to just the palmar surface of the terminal phalanx of the fifth finger and the opposing sides of the fifth and fourth fingers. The radial nerve does not have an autonomic dermal innervation zone.

When wounds occur high up on the upper limbs, in addition to the areas indicated above we must check sensitivity in the innervation zones of the medial cutaneous nerve of the arm, the medial cutaneous nerve of the forearm, the lateral cutaneous nerve of the forearm (from the musculocutaneous nerve), and the dorsal nerve of the forearm (from the radial nerve). Sensitivity impairments on the sole and toes accompanying wounds of a lower limb indicate injury to the tibial nerve, while sensitivity impairment on the top of the foot indicates injury to the fibularis nerve.

Objective description of the boundaries of areas with impaired sensitivity indicating the degree of impairment (anesthesia, hypesthesia, hyperpathy)

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and especially a schematic diagram of the boundaries of the area of impaired sensitivity have advantages over just naming the nerve.

Impairment of sweating to the point of anhydrosis is always observed within the same boundaries as anesthesia.

Vasculomotor disturbances are sometimes very noticeable in the first while after a nerve is severed. Breakage of vasodilatory nerves can cause hyperemia manifested as change in skin color and a rise in skin temperature. When injury occurs to the median nerve, for example, the first, second, and third fingers and the corresponding area of the palm become red and hot to the touch, and sometimes even somewhat edemic. When the ulnar nerve is severed the same changes may be observed on the part of the fourth and fifth fingers and the corresponding area of the wrist. In the presence of wounds of the tibial nerve the same phenomena are noted on the sole and the toes, and when the fibularis nerve is severed they are observed on the top of the foot.

In the event that large numbers of casualties arrive, use of modern electrophysiological analysis methods would be unrealistic. To permit initial hypothetical diagnosis of nerve injury it would be enough to perform an elementary investigation of movements and sensitivity.

Preliminary diagnosis of nerve injury would make it necessary to place the victim under observation in order to refine the diagnosis, determine the severity of nerve injury, and establish the indications for a particular form of therapy.

Principles of therapy: Correct organization of the evacuation and treatment of casualties with injuries to the peripheral nervous system has very great significance, since in past wars wounds coupled with injuries to limb nerve trunks made up a very large proportion of all unfavorable outcomes.

First medical aid: When injuries occur to limb nerve trunks, first medical aid would involve application of a protective dressing and immobilization of the limb for travel in accordance with the general indications.

First physician's aid: Emergency surgery is indicated at the OPM only in the event that nerve trunks are compressed by a growing hematoma or by edema, for example when major vessels are wounded, causing hemorrhaging between muscles. Surgery in such cases involves immediate and extensive resection of fasciae; otherwise serious irreversible alterations may occur within a large segment of the trunk in the very first hours.

Specialized treatment of casualties with injured nerves was one of the important achievements of the military medical service in the Great Patriotic War. Such wounds must be investigated and treated in specially established hoppitals for casualties with injuries to the peripheral nervous system. These hospitals must be outfitted with apparatus for electrophysiological

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analysis (electrostimulator, electromyograph, apparatus to determine ohmic skin resistance), and they should be staffed with specialists capable of: 1) Making a precise diagnosis of the form and degree of nerve injury, 2) performing restorative surgery on the nerve using electrodiagnosis on the operating table and the methods of microsurgery, and 3) providing sensible restorative treatment both prior to and after the operation. Attempts at performing restorative nerve surgery in the hospital for all casualties with limb wounds without refining the neurological and electrophysiological diagnosis must not be made.

Surgery is indicated in the first days when conduction is partially impaired, if there are grounds for hypothesizing partial severing of the nerve trunk in the presence of an incised wound or in the presence of a foreign body in the nerve. In the former case one or two sutures are applied to the epineurium, correcting the position of injured nerve tracts within the trunk and thus preventing formation of a lateral neuroma. In the latter case the foreign body is removed from the nerve.

In all other cases indications for emergency operations on injured nerves do not arise. The task of initial surgical treatment of a wound accompanied by injury to nerves is to create the conditions for the fastest possible healing of the wound, and not to restore injured nerve trunks. Attempts at applying primary sutures to a severed nerve discovered in a wound by chance usually terminate in failure. For such an operation to be successful, the ends of the nerve would have to be ideally refreshed, transverse sections would have to lined up precisely, the wound would have to be sutured closed, primary healing would have to occur, immobilization would be required for 3 weeks, and then the patient would have to be placed under observation to monitor recovery of movement with a consideration for the shortening and stretching of nerve ends that could have occurred when the sutures were applied.

Performance of postponed nerve operations early in specialized institutions during the first weeks and months following injury has its advantages. Further examination of the wound victims makes the provisional diagnosis of nerve injury a final diagnosis, if it is supported by objective data permitting a decision as to the degree to which conduction is impaired and the severity of nerve injury. Using electrodiagnostic methods, 3-4 weeks after injury we can precisely establish whether or not degeneration of injured nerves and muscles has set in. In cases of concussion coupled with temporary disturbance of conduction following gunshots wounds, movement and sensitivity recover by this time, and even sooner. A large group of casualties will be revealed, especially those with gunshot wounds, who would not need neural surgery.

Surgery is indicated in the first weeks and months after injury mainly when the severity of injury makes it necessary to resect injured portions of the nerve and apply an epineural suture. The extent of resection of nerve ends required with gunshot wounds is revealed at this time during surgery

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with sufficient definiteness. The epineurium is firm, and it should hold sutures well. Smooth healing of the wound is almost guaranteed. Indications for so-called neurolysis or for examination may arise soon after injury when diagnosis is adequate only as a exception. Later, months and years after trauma, once again the indications for neurolysis should arise very rarely, since this operation does not significantly alter changes occurring within the nerve trunk, and the plate-like scars on the nerve's circumference, the harmfulness of which is highly exaggerated, will form once again after a certain amount of time anyway. Supplying vessels approach the nerve from surrounding tissues along these scars.

When major blood vessels and nerves are wounded the priority task is to immediately restore the principal flow of blood. Emergency restorative surgery on a vessel should not be encumbered with simultaneous restoration of nerves; surgery can be performed on the latter without detriment to the outcome 2-3 weeks or more later, after the success of the restorative surgery on the vessel can be determined.

When nerve injury accompanies a fracture, the indications for surgery are defined by the extent of bone damage. If indications for bone surgery arise, surgery is performed on the nerve concurrently, as necessary. In most cases nerve injury accompanying fractures is caused by stretching, and the integrity of sheaths is not disturbed. In 80 percent of the cases injured nerves accompanying fractures recover on their own within the first few months after injury. If signs of delay in nerve regeneration arise in the presence of a fracture, neurosurgery is undertaken after a so-called acceptable waiting period, the time of which varies within 3-4 months, with a consideration for the degree of injury. When a gunshot fracture is complicated by osteomyelitis and long-lasting purulent fistulas, surgery required by complete anatomical breakage of the nerve must sometimes be undertaken jointly with bone surgery, especially if many months had passed since the time of wounding.

Combined injuries of nerves and tendons are encountered in peacetime mainly with incised wounds of the forearm and wrist, though they do occur with gunshot wounds as well. When diagnosing these injuries we must remember that impairment of flexion and extension in the interphalangeal joints in the presence of wounds of the lower and middle third of the forearm (or shank) is caused as a rule by injury to tendons, since branches innervating muscles of the forearm (or shank) originate from nerves in the upper third of the forearm (or shank). Restorative surgery on nerves after investigation of their conduction is indicated in the presence of such injuries after healing of the wound.

Late operations on nerves, months and years after wounding, are indicated when such operations had not been performed earlier for some reason. Satisfactory results can even be enjoyed when sutures are applied to a nerve many years after wounding, assuming that muscles continue to respond to electrical stimulation and contracture has been eliminated. A late operation

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on nerve trunks, if it is performed well, is a lesser evil to the patient and provides better results than repeated operations undertaken to correct mistakes made during application of the initial suture on the nerve.

Physical treatment methods: All victims with injury to limb nerve trunks require prolonged physical therapy both before and after the operation. It should be remembered that all surgery can do is create favorable conditions for regeneration of a nerve and restoration of its conduction following anatomical injury. Nerve regeneration is a lengthy process that terminates with adequate reinnervation of tissues and recovery of lost functions only on the condition that muscles, ligaments, and vessels remain healthy. All therapy must be aimed at promoting nerve regeneration and keeping denervated limb tissue in the most favorable condition possible. Such therapy must continue for several months after surgery, until the limb's functions recover. As with unsensible therapy, failure to provide regular therapy may mean that even a well performed operation on a nerve would be unsuccessful due to irreversible changes in limb tissues.

Therapeutic physical culture, massage, and electrostimulation of paralyzed and, later, regenerating muscles, and heat therapy promote regeneration of the nerve and recovery of limb functions. These methods must be implemented before surgery, as soon as possible after injury, assuming there are no contraindications on the part of the wound. Such therapy plays an even greater role in the recovery period following neurosurgery, when it is especially important to prevent distortion of the limb, protect muscles from atrophy and cirrhosis, and maintain an appropriate volume of movements in joints for a long period of time. Aid to casualties with injured nerves would be satisfactorily organized only in the event that adequate attention is afforded to physical therapeutic methods both before and after surgery.

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PART THREE

COMBINED INJURIES

CHAPTER 1

COMBINED RADIATION INJURIES

Combined radiation injuries arise in response to nuclear bursts as a result of the influence of two or three injurious factors upon man--light radiation, the shock wave, and penetrating radiation. The action of these factors is practically simultaneous at the time of the burst. Cases in which traumas and burns are combined with injuries caused by radioactive substances may be interpreted as an exception. When ground nuclear bursts occur, explosion products settle to the ground different distances away from the epicenter after particular time intervals depending on the power of the burst and wind speed.

The main distinguishing feature of combined radiation injuries is the mutually associated development of acute radiation sickness and mechanical injury or burns.

According to data cited by Oterson and Uorren (1960) combined radiation injuries following the nuclear bombing of the Japanese cities of Hiroshima and Nagasaki were observed in response to the action of the shock wave and ionizing radiation, in response to the combined action of light radiation and ionizing radiation, and in response to the combined action of the shock wave, light radiation, and ionizing radiation. Combinations of two types of injury following the atomic burst above Hiroshima were observed among 34.5 percent of the casualties, while the percentage of such casualties was somewhat larger in Nagasaki--37.1. Injury caused by three factors simultaneously occurred less frequently. Such a combination was noted among 5 percent of the casualties in Hiroshima and 5.2 percent of those in Nagasaki. These materials pertain only to nuclear bursts above Japanese cities. As we know from the literature (N. D. Ponikarov et al., 1965), there cannot be a nuclear burst in which all of the injurious factors would act upon an individual at a given point with maximum intensity. Interacting with the body, each of these injurious factors transmits only a particular quantity of energy to it. The

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effectiveness with which the individual injurious factors acts depends on the caliber of the nuclear burst, its type, the distance from the epicenter of the nuclear burst and, in a number of cases, the meteorological conditions and the nature of urban buildup.

White et al. (1964) present the dependence of change in the radii of the zones of injury by each of the factors on nuclear bursts of different power (Figure 46). The dependence explains the laws governing arisal of combined radiation injuries in response to bursts having power from 1 kiloton to 10 megatons. In relation to a burst of several kilotons, nuclear radiation has the greatest radius of injury, if we compare this radius with the radius of action of the shock wave or light radiation. But when the power of the burst is 10 kilotons the radius of injurious action of the shock wave and light radiation exceeds the radius of injury caused by penetrating radiation. Bursts of all sizes above 100 kilotons produce a radius of injury by penetrating radiation that is significantly smaller than the radii of injury of light radiation and the shock wave.

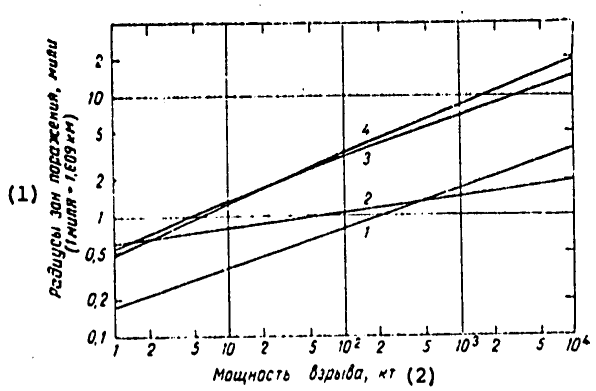

Figure 46. Dependence of Change in Zones of Injury Caused by Bursts of Different Power (From White et al, 1964): *1*--Radius of lethal injury by the shock wave; *2*--radius of clinically expressed injuries by penetrating radiation (200 r); *3*--radius of injuries caused by a shock wave with a probability of 50 percent; *4*--radius of arisal of degree II burns with a probability of 50 percent.

Key:
1. Radii of zones of injury, miles (1 mile=1.609 km)
2. Burst power, kilotons

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The overlap between the zones of action of one of the injurious factors of a nuclear burst and another factor explains the possibility of combined injuries. The possibility of combined radiation injuries is inherent to only nuclear bursts of particular power. As a rule the large doses of penetrating radiation accompanying low-power bursts can cause death in a short time following the burst without the additional influences of other injurious factors. In precisely the same way, the action of the shock wave accompanying a high-power burst will cause death in the presence of insignificant doses of radiation, or even in its absence.

Mutual development of acute radiation sickness and mechanical or thermal injuries is typified as a rule by mutual aggravation of pathological processes (A. N. Berkutov, 1955; B. M. Khromov, 1959; A. A. Vishnevskiy, M. I. Shrayber, 1968; V. A. Polyakov et al., 1969; E. Oterson, Sh. Uorren, 1960; T. Sirs, 1955, and others). The essence of the mutual aggravation syndrome is that presence of radiation sickness as a rule worsens the course and outcome of mechanical and thermal injuries, while presence of traumas or burns in turn worsens the prognosis of radiation sickness. Williams (1966) distinguishes two forms of mutual aggravation--additive, where interaction of each of the injuries is summed according the the principle one+one=two interactions, and synergetic, where interaction of each of the injuries is intensified in accordance with the principle one+one=three or more interactions.

Active interaction of two injuries that have occurred concurrently or at different times is observed very often as a summation of traumas of different natures, for example in the case of combined mechanical and thermal injury. Synergetic interaction of injuries should be interpretted as one of the typical features of the development of combined radiation injury.

Both forms of mutual aggravation develop depending on the nature and severity of each of the interacting injuries. Blood loss aggravates combined radiation injury only in the event that its dimensions achieve a certain value. L. S. Korchanov et al. (1958) noted that blood loss attaining 15-20 percent of the total mass of blood can lead to faster development of shock in the presence of combined radiation injury. Lower blood loss did not promote more frequent or earlier development of shock in animals with gunshot wounds and radiation sickness.

A fully definite mutual aggravation syndrome is observed with combined radiation injuries entailing bone fracture and radiation sickness.

The mutual aggravation syndrome is expressed even more with the combination of radiation sickness and burns (A. N. Berkutov, 1955; A. S. Rovnov, 1956, and others). Mutual aggravation of these injuries is distinctly manifested even in response to small radiation doses. Dawis (1955) and others note that a sharp decline in hemoglobin content and thrombocytopenia, an increase in blood coagulation time, change in the content of protein fractions, and more-expressive aplasia of bone marrow are observed in the presence of combined radiation burns.

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We can conclude from published information, basically experimental, that the degree of mutual aggravation witnessed with combined radiation injuries depends on the dose of ionizing radiation received and the nature and severity of trauma or burns.

A correct understanding of the unique features of combined radiation injuries would become possible only after familiarization with some aspects of the development of radiation sickness.

Ionizing radiation is an inadequate stimulus to the body, since it is devoid of special receptors and analyzers that can perceive such radiation. Radiation injury is a consequence of primary and secondary changes occurring in the body.

Primary changes are the result of absorption of radiation energy directly by the substance of the body's tissues. The primary mechanism of radiation's action on tissue is physicochemical: Atoms and molecules in the tissues undergo ionization and excitation. These atoms and molecules have great biochemical activity. Arisal of active ions elicits reactions atypical of the body, and it changes the course of metabolism. Formation of free radicals having unsaturated chemical valences and changes in water contained within the body are given dominant significance in the direct action of penetrating radiation on a biological substrate.

Secondary changes are associated with primary changes, and they are the consequence of disturbance of the vital activities of the body as a whole and its organs and systems. In this case disturbances in the functions of the nervous and humoral systems assume priority. In particular, depending on the dose of ionizing radiation, injury to the nervous system, the gastrointestinal tract, or hemopoietic organs may dominate. The significance of the principal syndromes developing in response to general irradiation of the body varies, and it depends entirely on the radiation doses experienced.

Four forms of acute radiation sickness are distinguished depending on the dominant pathogenic mechanisms (A. K. Gus'kova, G. D. Baysogolov, 1971, and others):

That involving primary injury to the nervous system (cerebral form);

that involving secondary injury to the nervous system (toxemic form);

that involving predominant injury of the gastrointestinal tract (intestinal form);

that involving predominant injury to hemopoietic organs (typical form).

The arisal of these forms of acute radiation sickness depends on the size of the radiation dose experienced. The cerebral form of acute radiation sickness develops in response to a radiation dose above 10,000 r, the toxemic form

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requires a dose of 5,000-10,000 r, the intestinal form occurs in response to 1,000-5,000 r, and the typical form occurs at doses below 1,000 r. Doses below 100 r should be interpreted as the preclinical range.

For practical purposes a physician working in evacuation stages of the civil defense medical service would have to know the possible outcomes of injuries caused by penetrating radiation. According to published data the prognosis becomes hopeless with radiation doses above 1,000 r. Death may occur in from 1.5 to 2 months following a radiation dose greater than 200 r. The frequency of such an outcome climbs to 80 percent when the radiation dose is 600 r. The promptness with which proper treatment is rendered has a significant influence on the outcome of acute radiation sickness.

In the event the individual is injured by a higher dose of penetrating radiation, his death occurs sooner.

Table 10 presents the most typical information concerning the clinical manifestations of short-term irradiation of people.

The diagnosis of acute radiation sickness is based on medical history data and the results of clinical and laboratory analyses (A. K. Gus'kova, G. D. Baysogolov, 1971). These most reliable methods for identifying radiation injury require observation of the victim for a certain length of time, which the physician would not have when rendering aid to large numbers of casualties arriving at the medical evacuation stage.

D. Williams et al. (1966) believe that biological dosimetry is a difficult problem to resolve given the existing level of knowledge, and it would in fact be impossible to resolve when large numbers of casualties will be concerned. Physicians handling a large influx of casualties will rarely be able to learn the exact dose of radiation which they had received. The task of a physician sorting casualties suffering combined radiation injuries will be to determine those who had received a dangerous radiation dose.

It is difficult to make a diagnosis and evaluate the severity of a casualty's condition in the first 24 hours after injury by ionizing radiation. After 48 hours the clinical pattern of radiation injury becomes clearer: We can distinguish not only those requiring palliative therapy but also those victims for whom therapy would be successful or possible. In the first hours after injury it is impossible to isolate persons subject to treatment from among the masses of individuals injured by penetrating radiation arriving at the medical point because of the lack of distinctiveness of clinical manifestations. This would be possible only when the total radiation experienced is equal to the average lethal dose.

The methods of physical dosimetry are enjoying considerable acceptance as the means for determining the dose of ionizing radiation. Measurements are made with personal or group dosimeters. The accuracy with which the radiation dose is measured depends on the precision of the dosimetric instrument and the uniformity with which the body is irradiated.

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Table 10. Clinical Effects Accompanying Short-Term Irradiation at Various Doses (From A. K. Gus'kova and G. D. Baysogolov, 1971)

Range of Doses and Clinical Effects; Index	0-100 r, Preclinical Range	100-1000 r, Therapeutic Range (Therapy May Be Effective)			Over 1000 r, Lethal Range	
		100-200 r	200-600 r	600-1000 r	1000-5000 r	over 5000 r
		Clinical Observation	Successful Therapy	Possible Therapy	Palliative Therapy	
Nausea	None	100 r--5 % 200 r--50 %	from 300 r-- 100 %	100 %	100 %	
Time of Arisal of Primary Reaction	—	3 hours	2 hours	1 hour	30 min	
Principal Organ Injured	None	Hemopoietic Tissue			Gastrointestinal Tract	Central Nervous System
Typical Symptoms	None	Moderate Leukopenia	Severe Leukopenia, Purpura, Hemorrhaging, Infection, and Depilation at Doses Greater than 300 r		Diarrhea, Fever, Disturbance of Electrolyte Balance	Convulsions, Tremor, Ataxia, Lethargy
Times Critical Changes Arise After Irradiation	—	—		4-6 weeks	5-14 days	1-48 hours
Therapy	Psychotherapy	Psychotherapy, Hematological Observation	Blood Transfusion, Antibiotics	Bone Marrow Transplant Possible	Support of Electrolyte Balance	Sedatives
Prognosis	Favorable	Favorable	Cautious	Unfavorable	Hopeless	

[Table continued on following page]

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Table 10 [Continued]

Recovery Time	—	Several Weeks	1-12 months	Lengthy	—				
Mortality	—	—	Variable, 0-80 %	Variable, 50-100 %	90-100 %				
Time of Death	—	—	1.5 months	2 months		2 weeks	1-3 days		
Cause of Death	—	—	Hemorrhaging, Infection			Circulatory Collapse	Impaired Breathing, Cerebral Edema		

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Important significance is attached to manifestations of the body's initial general reaction and the time of its onset in relation to identifying the severity of acute radiation sickness. The signs of the initial reaction and the time of its arisal are correlated quite closely with the severity of radiation injury.

A number of laboratory analysis methods have been proposed for diagnosis of the form and degree of acute radiation sickness. The most convenient among them is analysis of peripheral blood--the decrease in erythrocytes and hemoglobin, leukopenia with a leukocyte count of 1,000 and less (in the first 24-36 hours), and thrombocytopenia.

In addition to these methods for identifying radiation injuries, quick methods have been suggested based on analyzing the concentration of free amino acids in urine (creatinine and taurine, as well as β-aminobutyric acid are believed to be the most important for these purposes), on determination of the cytological changes in the testes and of the concentration of iron in blood plasma, on investigation of chromosomal aberrations, and so on. But an acceptable technical concept making these methods usable in the practical work of therapeutic institutions has not been found.

An analysis of the methods for diagnosing acute radiation sickness aimed at identifying the radiation component of combined radiation injuries would allow us to note that the presence and expressiveness of the signs of the initial reaction, depilation, and changes in the blood picture could be used for diagnostic and prognostic purposes in the civil defense medical evacuation stages. These assessments cannot be viewed as dependable data for a general prognosis of radiation sickness, but in combination with dosimetric indices they do provide a possibility for a tentative conclusion concerning the severity of radiation injury. Difficulties arise in the diagnostic use of some early manifestations of radiation sickness when the symptoms of injuries caused by two burst factors coincide. As an example vomiting accompanying cerebral trauma hinders identification of radiation injury on the basis of the symptom complex accompanying the initial reaction. But subsequent depilation would be the grounds for a more-specific diagnosis. By determining the length of the latent phase of illness, the time at which thrombocytopenia and anemia are revealed, and the expressiveness and stability of lymphopenia we can make certain prognostic conclusions concerning the severity of the radiation component of combined radiation injury. In this case the length of the latent period of acute radiation sickness may decrease and leukopenia and hypochromic anemia may develop earlier, depending on the severity of the mechanical injury or burns suffered by a victim with combined radiation injury.

If nuclear weapons were to be employed, treatment of persons with acute radiation sickness would be taxed by difficulties associated with mass arrival of casualties. In particular, abandonment of the optimum volume of therapeutic measures and postponement of treatment of persons with identified degree I acute radiation sickness in the early stages of evacuation is recommended.

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Nevertheless the basic premises concerning the orientation of therapeutic measures implemented against acute radiation sickness must be observed. Special attention is turned to prevention and treatment of infectious complications, and to preventing hemorrhagic complications. When treating acute radiation sickness we cannot forego measures that would insure maintenance of reactivity of all of the casualty's organs and systems. Measures aimed at controlling intoxication and dehydration of the body during the initial reaction to irradiation, and use of painkillers and other preparations of symptomatic therapy have great significance in this regard.

Use of antihistamines (dimedrol and so on) in response to the initial reaction, administration of fluids and sodium and calcium chloride solutions, and transfusion of plasma, polyvinyl pyrrolidone and polyglucin must be based strictly on the indications. Transfusions aimed at blood replacement must be performed in the third and fourth phases of illness, while blood plasma transfusion should be performed only in the presence of pronounced hypoproteinemia and the hemorrhagic syndrome. Prompt prescription of antimicrobial preparations (antibiotics, sulfanilamides, gamma-globulins, and so on) should promote suppression of not only exogenous but also endogenous microflora responsible for septic complications. Antibiotics with a broad spectrum of action should be used for this purpose in large doses, mandatorily monitoring sensitivity to them. DNA preparations, vitamin-amino acid complexes, and other general strengthening agents are indicated in the third phase of radiation sickness.

The discussion above gives an indication of the importance of capitalizing upon the latent period of radiation sickness to treat mechanical and thermal injuries accompanying radiation injuries. However, a number of problems do arise in this regard:

Correct identification of the presence, form, and severity of acute radiation sickness in a casualty of a nuclear burst, in the event that he had experienced trauma, burns, or their combination;

identification of the severity of mechanical or thermal injury in the presence of pronounced signs of acute radiation sickness;

provisional determination of the time of onset of the phase of clinical well-being in the course of acute radiation sickness accompanying combined radiation injury with the purpose of determining the best time for surgery;

determination of the possibility for rehabilitation in an effort to save the life of a casualty with combined radiation injuries;

determination of the probability and nature of complications accompanying the given form of combined radiation injury.

Successful solution of the list of problems would be promoted by proper organization of aid rendered to casualties with combined radiation injuries in the medical evacuation stages. The structure of institutions in the

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civil defense medical service does not include institutions specialized for the treatment of persons with combined radiation injuries. This is why treatment of this contingent is assigned to institutions with a surgical profile. When considering the problems of organizing medical aid to casualties with combined radiation injuries, we must consider the unique features associated with the mutual aggravation syndrome.

The typical manifestations of the mutual aggravation syndrome are:

Shortening of the latent period of acute radiation sickness;

earlier and more-pronounced manifestation of hypochromic anemia and leukopenia in comparison with manifestation of these symptoms in the presence of the more-frequent forms of radiation sickness;

retardation of wound healing and repair processes during consolidation of fractures, and arisal of secondary hemorrhaging;

earlier and higher mortality among wounded individuals and burn victims.

High mortality among victims with combined radiation injuries is to a significant extent the product of a significant loss of fluids due to vomiting, diarrhea, or through the burned surface, the hemorrhagic syndrome, infectious complications resulting from suppression of the immunity reaction, leukopenia, and blockade of the reticuloendothelial system, in addition to interaction of the mechanisms of injury.

An analysis of data already published would allow us to conclude that it is possible and suitable to isolate a number of forms of combined radiation injuries. Such a classification can be based on assessments of the severity of injuries, their outcomes, and the prospects for applying therapeutic measures. Since it does not embrace the entire diversity of possible combinations of injuries in response to a nuclear burst, and because the details of particular cases are not given, such a classification could be recommended as a means for orienting medical personnel sorting casualties, and for determining the priority and volume of medical aid. Thus this classification will be more of organizational significance. It may be found to be convenient for sorting in the medical evacuation stages, but it should not at all preclude the physician's thoughtful attitude toward the victim or utilization of the entire arsenal of known resources and techniques for identifying mechanical, thermal, and radiation injuries.

Extremely severe combined radiation injuries include all cases of traumas and burns combined with radiation injuries that are prognostically unfavorable or hopeless.

Severe combined radiation injuries are severe and moderately severe mechanical and thermal injuries combined with irradiation in doses making a cautious prognosis of radiation sickness necessary.

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Moderately severe combined radiation injuries include traumas and burns with a favorable prognosis and combining with radiation sickness of prognostically equivalent degree of severity.

Mild combined radiation injuries are light traumas and burns combining with irradiation by a dose of not more than 100 r.

The suggested classification, which is based on the prognosis of combined radiation injuries, permits a physician faced by large numbers of casualties to tentatively subdivide casualties into four groups and determine the volume and priority of medical aid at the OPM. Persons with extremely severe combined radiation injuries will require palliative assistance. Victims with severe combined radiation injuries will require antishock measures and surgery as soon as possible after arriving at the therapeutic institution, treatment of wounds to prevent infection, and treatment of acute radiation sickness as required by the indications. Surgical treatment of persons with moderately severe combined radiation injuries may be postponed, but such individuals must remain under a physician's observation; surgery can be performed after all emergency operations are performed, as required by vital indications. This category of victims will require prevention of wound infection as well as treatment of radiation sickness first of all.

Victims with mild combined radiation injuries may receive first aid on the order of self- and mutual aid. But these persons would require an examination by a physician a certain time later for the purposes of refining the diagnosis and rendering assistance in the event of deterioration of condition. Prompt prevention of infectious complications is important to this category of victims.

Therapeutic measures implemented against combined radiation injuries depend on the unique features of the injuries, and mainly on mutually associated development of the clinical course of mechanical traumas or burns combined with radiation sickness. A combination of several illnesses would by itself predetermine the need for a complex of therapeutic measures.

Sensible combination of surgical aid in accordance with the specific features of wounds and burns, and therapeutic aid depending on the severity of radiation sickness should be recognized as the fundamental premises of complex treatment of combined radiation injuries. A very important factor is revealed in this case: Therapeutic measures that improve the course and outcome of mechanical and thermal injuries have a favorable effect on the course and outcome of radiation sickness; moreover, successful therapy of radiation sickness improves the course and outcome of traumas and burns. Mutually associated development of pathological processes requires treatment corresponding to the appropriate phases and periods of disease development in relation to not only the nature and volume of therapeutic measures but also the time of their prescription.

The problems of treating combined radiation injuries have been studied experimentally for the most part. The bulk of the suggested measures

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have not enjoyed their necessary confirmation in surgical practice. Only the use of antibiotics (penicillin) has been tested with positive results in Japan following the atomic bomb bursts. Treatment of such patients is rather complex. It must be conducted on the basis of the sensible use of a complex of therapeutic measures prescribed individually.

The general principles of rendering aid to victims with combined radiation injuries when the casualty count is large must foresee the return of the largest possible number of people to ther normal activity within the shortest time possible. The rehabilitation program must be applied primarily to those casualties for whom relatively simple interference or treatment of short duration would significantly improve the prognosis. To a certain extent this premise must also be extended to those cases of combined radiation injuries in which medical aid will significantly improve the prognosis. In the first stages of medical aid, casualties who would require a significant amount of time or participation of skilled specialists for their treatment, should receive only emergency aid, as defined by the vital indications, or maintenance therapy. The structure itself of the therapeutic-preventive institutions of the civil defense medical service obligates us to adhere to these principles.

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CHAPTER 2

TRAUMAS COMBINED WITH RADIATION SICKNESS

Persons with mechanical traumas combined with radiation sickness made up 17.7 percent of all casualties remaining alive on the 20th day after the atomic burst in Hiroshima, and 23.4 percent in Nagasaki.

The structure of mechanical injuries has great significance, but it is not presented very completely in the available literature (Table 11).

It stands to reason that persons with the most severe mechanical injuries who did not receive the necessary medical aid in the first days died early. A large number of victims died in collapsed buildings during fires.

Table 11. Frequency of Different Types of Mechanical Injuries Among Persons Remaining Alive on the 20th Day After Atomic Bombing of Japanese Cities

(1) Вид механических повреждений (в % к общему числу поражений)			
(2) переломы костей	(3) раны мягких тканей	(4) контузии (ушибы)	(5) травма головы
11	37	52	—
5—6	—	—	15—20
—	50	—	—
2	60	37	—
4,5	—	—	—
11	35	56	6
11	35	54	—

Key:

1. Type of mechanical injury (percent of total number of casualties)
2. Bone fractures
3. Soft tissue wounds
4. Contusions
5. Head trauma

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Table 12. Frequency of Mechanical Injuries (Percent of Total Number of Casualties)

(1) Число обследованных	(2) Частота механических повреждений	(3) Частота непосредственных повреждений	(4) Частота вторичных повреждений
3942	60,4	—	60,4
798	100,0	—	100,0
—	75,0	—	75,0
—	70,0	—	70,0
—	70,0—80,0	—	70,8—80,0

Key:
1. Number examined
2. Frequency of mechanical injuries
3. Frequency of direct injuries
4. Frequency of secondary injuries

Secondary or indirect injuries--that is, those caused by the body hurling against some sort of hard objects or by blows fromairborne glass fragments, brick chunks, stones, and tree limbs--were the dominant injuries caused by the shock wave produced by the nuclear attack on Japan. The direct influences of the shock wave, manifested as injuries to the lungs, stomach, and intestines andas hemorrhaging of internal organs, did not have dominant significance in Japan, since persons near the burst epicenter were buried beneath the ruins of buildings or died in the first days from burns or radiation sickness. All communications written by foreign authors emphasize that observation revealed no injuries to internal organs caused directly by the shock wave.

Table 12 presents data on the frequency of secondary injuries in response to the atomic bombings of the Japanese cities.

Were we to examine the data on the bombings of the Japanese cities in application to nuclear bursts of other power, in addition to an increase in the area of destruction of urban buildup we may expect a decline in the number of combined radiation injuries involving various forms of traumas and radiation injuries.

Wounds

The dynamics of the wound process on the background of radiation sickness have a number of unique features stemming from inhibition of repair processes. The degree to which these disturbances are manifested is associated with the severity and the phases of development of radiation sickness.

E. Oterson and Sh. Uorren (1960) present a description of the course of the wound process in Japanese citizens injured by lethal doses of penetrating radiation; this description is taken from a report of Military Hospital No 1 in Tokyo:

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"Healing of wounds took longer, and it coincided with arisal of typical symptoms of the action of penetrating radiation. Granulations became anemic and edemic. Such tissue bled slightly or became dry due to an abrupt decline of excretions. The wounds margins were eroded: Growth of granulations stopped, and no tendency for healing could be observed. In some cases the wound gradually increased in size and failed to heal until the time of death. Among victims who remained alive development of granulations resumed as they recovered from radiation sickness."

It was established experimentally that wound healing is not disturbed as a rule in the first and second phases of radiation sickness. In the third phase of radiation sickness the course of the wound process begins to differ significantly from the process with which we are generally familiar. The wound healing rate decreases. Later, dead portions of tissue are rejected, growth of granulations sometimes ceases completely, the granulations are anemic, readily wounded, and often bleeding (V. I. Murav'yev et al, 1956; A. N. Berkutov, 1956, and others), the inflammatory reaction is weakly pronounced, and a line of demarkation is almost absent. Formation of connective tissue is dramatically suppressed, and its transformation into scar tissue is retarded. In a number of cases necrosis develops around the margins and floor of the wound.

Because repair processes diminish in vigor and the permeability of tissue barriers rises due to radiation sickness, infection undergoes swift development.

It has been pointed out that wound infection was the principal mortality factor among victims of the atomic bomb bursts in Japan. Superficial wound infection was a common phenomenon among persons with combined radiation injuries, though cases of infectious complications of even greater seriousness were encountered.

Tetanus and gas gangrene were observed relatively rarely. Tetanus was observed among 3 out of 758 wound victims at the naval hospital in Omura, and there were 4 out of 350 wound victims in another hospital. The lower incidence of tetanus among the casualties of the nuclear burst than among Japanese soldiers wounded in battle can apparently be explained by a lower degree of contamination of the clothing of urban residents and the more-superficial nature of the wounds themselves.

Because wound healing cannot occur in the second phase of radiation sickness in view of its shortness, this process occurs in the fourth phase. In this case we often observe instability of the scar tissue formed, ulceration of scars, and late suppuration. Such a wound course often leads to development of serious septic complications.

The effect of radiation sickness on the phasal course of the wound process is typified by the following signs:

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Edema that is more highly pronounced than with an ordinary wound develops, and necrosis of muscle fibers increases and proceeds for a longer time in the initial cleansing phase;

leukocyte migration declines, collateral edema persists for a long time, the expressiveness of the leukocytic spindle is reduced or it is absent, and rejection of necrotic tissues is retarded in the inflammation phase;

repair processes are retarded, hemorrhaging arises, and formation of young connective tissue and its transformation into scar tissue are suppressed in the regeneration phase.

Thus necrobiotic processes dominate over repair processes in the presence of radiation sickness. These changes are observed with degrees II and III of the typical form of radiation sickness.

The effect of the wound on manifestation of radiation sickness, experiments on animals show (V. I. Murav'yev et al, 1957; B. M. Khromov, 1958, and others), is expressed in short-term leukocytosis as a reaction of the irradiated organism to the trauma inflicted and absorption of the products of autolysis and impaired metabolism from the wound. Complications of the wound process--wound infection, hemorrhaging, and retarded healing--have the greater influence on the course of radiation sickness.

Wound infection reduces the time of onset of the manifestations of acute radiation sickness; in particular the second phase shortens and the hemorrhagic syndrome becomes more expressive. Infectious complications in the wound become especially severe in the third phase of acute radiation sickness, when the course of radiation sickness itself acquires traits inherent to sepsis.

Hemorrhaging from the wound promotes significantly faster development of anemia. Retarded blood coagulation and arisal of the first signs of a decrease in the resistance of vascular walls at the end of the second phase of acute radiation sickness promote development of such hemorrhaging.

Retardation of wound healing, which continues into the third phase of acute radiation sickness, is found in a number of cases to be incompatible with the organism's normal vital activities in connection with profound affliction of the blood system, inhibition of immunity, and development of a pronounced hemorrhagic syndrome. General infectious complications (sepsis) are the principal threat to the lives of persons with combined radiation injuries having wounds that do not heal for a long time.

Treatment of soft tissue wounds on the background of acute radiation sickness involves, as with conventional wounds, prevention of wound infection and its treatment. The success of treating combined radiation injury depends on the whole on the sophistication of the methods for treating the wound process and the promptness with which the acute radiation sickness is treated.

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Initial surgical treatment continues to be the principal preventive measure. It has been demonstrated experimentally (V. I. Murav'yev et al, 1957; L. S. Korchanov et al, 1958; A. N. Berkutov, 1956, and others) that initial surgical treatment of wounds in the first and second phases of acute radiation sickness does not have a significant influence on the general conditions of animals. Surgical treatment of wounds in the third phase of acute radiation sickness involves difficulties stemming from the greater amount of bleeding experienced by tissues.

When surgical treatment must be postponed, antibiotics must be used early (A. N. Berkutov, 1956; B. M. Khromov, 1959; Williams et al, 1966, and others).

Persons performing medical sorting at the OPM must first of all consider the severity of radiation sickness, since in the presence of wounds its severity predetermines the surgical tactics when large numbers of casualties are involved. In this case the possible duration of the second phase of radiation sickness (the latent period) and the form of this disease must be taken into account. Minimization of the time favoring surgical intervention obligates the surgeon to place such casualties into the group requiring initial surgical treatment at the earliest opportunity.

Both the wound itself and acute radiation sickness must be treated in institutions of the hospital base. Use of plastic surgery to close previously treated wounds acquires great significance at the specialized stage in the treatment of wounds accompanying combined radiation injuries.

Temporary sutures of all three variants--initial-postponed, early secondary, and late secondary--should enjoy broad application. Surgery is indicated in the presence of infectious complications of wounds irrespective of the phase of acute radiation sickness.

Bone Fractures

The effect of penetrating radiation on the course of bone fractures has been studied experimentally. Information on such combined injuries in Japan is limited to communications stating that the condition of casualties deteriorated and mortality increased when they were moved from one city to another. The lack of information on the course of bone fractures occurring with acute radiation sickness in the materials concerning the atomic bombings of Japan can be explained by the low number of such radiation injuries in comparison with, for example, the number of burn cases, to which the principal attention was devoted in the published descriptions of injuries.

According to data cited by L. D. Podlyashuk and V. Ya. Fridkin (1949), M. F. Volkov (1967) and others, bone tissue is extremely sensitive to the external effects of penetrating radiation, which lead to decalcination, resorption, osteoporosis, and even bone necrosis. The expressiveness of the changes in the bones depends on the dose of external radiation experienced.

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Retardation of bone tissue regeneration is believed to be the principal manifestation of the influence of acute radiation sickness on the course of bone fractures (M. N. Pavlova, 1955; I. L. Krupko, 1957; S. S. Tkachenko, 1958, and others). In this regard bone tissue reacts to irradiation of the body in the same way as do other tissues. Formation of a callus following exposure to ionizing radiation at doses causing 50 percent animal mortality in control experiments may proceed twice slower than in healthy animals. Moreover formation of a callus is imperfect: Resorption of previously formed bone elements and a tendency to form false joints are observed (M. D. Abdulayev, 1957; B. M. Khromov, 1959; V. A. Polyakov et al., 1967, and others).

P. D. Gorizintov (1958) and others believe humoral disturbances to be one of the principal pathogenic factors of acute radiation sickness. In particular, growth in a negative nitrogen balance due to breakdown of proteinaceous structures can lead to change in the structure of collagen fibers. For this reason alone, local disturbances in callus formation should be viewed as an indication of the effect of acute radiation sickness on regeneration of bone tissue.

As with wounds and radiation sickness, the mutually associated course of bone fracture and radiation sickness contributes certain difficulties to clinical identification and assessment of the severity of the radiation component. In particular, experiments have shown that leukocytosis is observed in the first 1-2 days after combined radiation injury of this type, and leukopenia developing after this is less pronounced than after the body is subjected to just general irradiation alone.

Observations made by L. S. Korchanov et al. (1958), M. I. Ul'yanov (1967), and others have shown that in the presence of infected compound bone fractures combined with acute radiation sickness, changes in blood indices, which have significance to diagnosis of acute radiation injury and its severity, experience similar changes, in distinction from their typical development in the presence of acute radiation sickness.

When numerous casualties suffering bone fractures combined with acute radiation sickness arrive at the medical evacuation stages, the variability of blood indices would be extremely extensive due to differences in both the severity of mechanical injuries and the total radiation dose experienced. Nonuniformity of the total radiation dose experienced by the body in urban buildup would in turn have a significant influence on its variability. Such features of combined radiation injuries hinder diagnosis of the radiation component, which leads to an incorrect assessment of its severity (usually in the direction of reducing the degree of acute radiation sickness), and to inaccuracies in determination of the most acceptable times for surgical treatment of bone fractures.

Treatment of bone fractures accompanying combined radiation injuries must be based on the general principles of fracture treatment, and mainly it should consider the location and nature of the fracture. The most sparing method must be chosen when treating casualties having combined radiation injuries.

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Experimental data available today on the treatment of bone fractures accompanying combined radiation injuries can be assessed to a great extent as theoretical, indicating only the possibility for the use of one method or another from the standpoint of the course and knitting of the fracture. But there are grounds for believing that all of the known methods of treating bone fractures will enjoy application.

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CHAPTER 3

BURNS COMBINED WITH ACUTE RADIATION SICKNESS

In a war in which nuclear weapons are used, a significant percentage of the people are subjected to the combined influence of penetrating radiation and the thermal agents. Several variants of the action of these injurious factors on the body are possible:

Simultaneous injury of the body by penetrating and light radiation at the moment of the nuclear burst, as was the case for a significant proportion of the victims of the atomic attack on the Japanese cities of Hiroshima and Nagasaki;

first thermal injury and then radiation injury, which would be possible when the burn victim is exposed to radioactive fallout;

first the action of penetrating radiation and then the thermal factor, for example burns on people irradiated by small doses or who have suffered mild radiation sickness.

It should be considered in this case that these injurious factors may act upon the body differently depending on a number of attendant factors. Thus acute radiation sickness may develop in response to relatively uniform external gamma-neutron irradiation, or due to nonuniform external irradiation with the dose selectively higher on some particular part of the body or, finally, as a result of repeated, multiple, and prolonged irradiation (G. I. Alekseyev, 1971).

Thus when we evaluate the clinical course of combined injuries we must consider both the succession and the different features of the action of a nuclear burst's penetrating and light radiation on the body.

Specific Features of the Development of Combined Burns and Radiation Injuries

When injurious factors act upon the body simultaneously, burn shock develops on the background of initial reactions to irradiation, and the septicotoxemic

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period of burn disease coincides with the peak of radiation sickness. If the thermal or ionizing effect occurs earlier, this mutual relationship may be disturbed, and the most diverse "superimpositions" of the developmental phases of burn disease and radiation sickness would arise.

Research has shown that when combined injury occurs the pathological process affects the nervous and cardiovascular systems, the endocrine glands, and hemopoietic organs, metabolic processes are disturbed, the body's defenses are weakened, and so on.

Ionizing radiation causes certain predictable changes in the functional state of the central nervous system.

Significant changes are also observed in protein metabolism in response to combined injuries. The main one is an increase in globular proteins due to a decrease in the concentration of albumins (A. V. Popel', 1957). One of the causes of changes in the blood protein composition is an increase in vascular permeability. Under the influence of radiation, the permeability of vessels increases first in radiosensitive organs (the small intestine, the spleen, and so on) and then, as the disease develops, in other systems and tissues.

When thermal trauma occurs, disturbance of vascular permeability is first noted in the area of the burn. Later the permeability of vessels experiences a moderate, general increase.

When combined injuries occur, barrier systems become permeable earlier and their permeability is more highly pronounced than with the isolated action of radiation or burns.

The accelerated decline of the blood albumin content in the first 2 hours after combined injury is apparently associated with its discharge in the burn area, since recovery of normal vascular permeability in the injured area, noted a day later, leads to normalization of the blood albumin content. The subsequent increase in the yield of labeled albumin is obviously the product of generalization of the increase in permeability of barrier systems.

Concurrently with disturbance of the permeability of vascular and tissue barriers, the natural resistance of the irradiated organism weakens abruptly. It has been established that development of radiation sickness inhibits the phagocytic activity of cells in the reticuloendothelial system, decreases the bactericidal properties of blood serum, retards antibody formation, and so on. Changes occurring in the irradiated organism promote autoinfection, gastrointestinal bacteria being the source. In the presence of combined injuries the burned surface is an additional entryway for infection. Thus reduction of the body's general resistance in the presence of combined burn and radiation injury promotes arisal of infectious complications (L. S. Korchanov et al., 1958, and others).

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Serious disturbances occur in the hemopoietic system in response to combined injuries. Change in hematological indices is closely associated with the developmental phases of burn disease and radiation sickness. It would be important to emphasize that the hematological shifts occurring in response to combined injury are not the simple sum of changes observed in the presence of each trauma taken separately, instead being characterized by a number of specific features. These features are mainly the product of the severity of the radiation and thermal effects. Thus when mild or moderate radiation sickness occurs with burns that are not serious, leukopenia may develop later than in response to irradiation alone. On the other hand when thermal injuries are severe the changes specific to radiation sickness arise much sooner than in animals exposed only to radiation at the same doses (O. V. Florova, 1965; V. N. Legeza, 1969, and others).

Thus changes arising in the body due to irradiation are responsible for the different responses to additional thermal trauma, and on the other hand burn trauma has a significant influence on the manifestation and course of radiation sickness.

Clinical Course of Combined Burn and Radiation Injuries

It was established in an experiment on different species that burn shock generally proceeds in irradiated animals in accordance with all of the laws inherent to it. But when intense thermal trauma is inflicted after irradiation causing development of radiation sickness, the erectile phase of shock usually lasts longer in experimental animals than in control animals. If burns are caused at the peak of radiation sickness, the erectile phase of shock shortens or does not develop at all (L. I. Rodina, 1962; V. A. Suvorov, B. A. Saakov, 1963; A. A. Sureymenov, 1966, and others). In the erectile phase of burn shock, following a short-term increase arterial pressure typically remains close to the initial level (V. K. Zen'kov, 1967).

The torpid phase of shock in irradiated animals is shorter and proceeds much more severely than in animals subjected to thermal injury alone. In this period arterial pressure exhibits a tendency for sinusoidal fluctuation: Periods of increase alternate with periods of decrease; on the whole it remains at a relatively high level and declines abruptly only prior to the animal's death. Blood deposition begins and the mass of circulating blood decreases early in the torpid phase of shock. The hemodynamics of the pulmonary circulation suffer an especially great deal in view of enlargement of the right half of the heart, dilation of major vessels, and reduction of blood flow rate (P. N. Mazayev et al., 1969).

Considering that a number of serious disturbances arise in the central nervous, endocrine, and cardiovascular systems, in metabolic processes, and so on in response to severe combined radiation injuries, shock generally develops much more frequently and proceeds much more severely than in the presence of thermal trauma alone (A. S. Rovnov, 1956; V. M. Khromov, 1959, and others).

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Subsequent development of combined injury also depends in many ways on the mutual aggravation of burn disease and radiation sickness. As a result the effect of the combined action of ionizing radiation and thermal trauma may differ significantly from the phenomena observed with the action of each of these injurious factors alone.

But in those cases when the severity of one of the types of injury is relatively low the disease develops without signs of mutual aggravation.

In addition to aggravation of the course of radiation sickness, when combined injury occurs we can also note local disturbances in the course of burn disease (V. M. Burmistrov, 1970, and others).

Significant deviations from the usual clinical course of a burn wound are not observed in the latent period of radiation sickness, since the principal components of the wound repair process--inflammation and regeneration--are not suppressed yet in this period.

Significant disturbances appear in the course of the local wound process at the peak of radiation sickness. The inflammatory reaction in the burn area is inhibited while rejection of necrotic tissues, formation of granulations, and epithelialization are retarded. Hemorrhaging appears, first spotty and later diffuse. Hemorrhaging is especially pronounced beneath the burn scab. The granulations that do form do not reach their normal maturity. Intensified reproduction of bacteria is noted in the burn area and in adjacent tissues. In severe cases regressive changes begin in wound tissues; in particular, granulations already formed undergo necrosis (A. A. Vishnevskiy, M. I. Shrayber, 1968).

According to N. N. Mudretsov and V. M. Chernykh (1964) sepsis is encountered six times more frequently with severe combined radiation and burn injuries than with radiation sickness not involving burns.

The second most frequently encountered complication is pneumonia, which was often noted among the victims of the atomic bombings in Japan, especially those who died in the 3d-6th week after the atomic bursts. So-called necrotizing leukopenic pneumonia characterized by an extremely severe course arises predominantly at the peak of radiation sickness.

During the time of resolution of radiation sickness the repair and regenerative processes begin to gradually recover. The burn wound is cleansed of necrotic tissues, viable granulations develop, and regeneration of the epidermis and connective tissue begins. These disturbances in the course of the wound process at the peak of radiation sickness significantly lengthen the time of burn wound healing.

Treatment of Combined Radiation and Burn Injuries

First medical aid is rendered for burns combined with effects of penetrating radiation in accordance with the general rules. The principal attention

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should be turned to preventing burn shock. For this purpose painkillers should be injected into the victim irrespective of the surface area of the burns, aseptic dressings should be applied, the victim should be immobilized for travel as necessary, and he should be evacuated swiftly and carefully if possible.

First physician's (skilled) aid is rendered basically in accordance with a common plan, antishock therapy being provided to both casualties with "clean" burns and those with combined radiation and burn injuries. Considering that the erectile phase of shock may last longer in the presence of combined injury, use of neurotropic agents, neuroplegics, and bromides would be indicated in these cases (B. M. Khromov, 1959). In view of the unique features of combined injury, the body's responses to any manipulations performed and to the preparation administered may be distorted. Thus Smith (1961) believes administration of ACTH at the time of shock to be contra-indicated while P. P. Saksonov et al. (1963) recommend decreasing the dosage of lobeline and cytiton by a factor of two and that of corazole and camphor by a third. The body's reactivity to medicinal agents changes especially dramatically at the peak of radiation sickness. During this period respiratory analeptics suppress the respiratory center, while camphor and corazole suppress respiration and cardiovascular activity rather than intensifying it. Injection of epinephrine in the initial and latent periods of acute radiation sickness produces an insignificant vasoconstrictive effect, this effect being quite pronounced on the other hand at the peak of acute radiation sickness. Change in the body's response to administration of medicinal preparations must be accounted for when prescribing therapy.

The treatment of victims with combined injuries in the period of the development of toxemia and septicotoxemia, and during the peak of radiation sickness must be aimed at controlling intoxication, hypoproteinemia, infection, anemia, and any arising complications. Considering that in the presence of combined injuries the disturbances arising in all of these phases of disease development are more serious than those encountered with each trauma separately, the therapy would also have to be more intense. But in order to achieve a therapeutic effect we would have to increase the dosage or frequency of administration of blood and its preparations, blood substitutes having detoxifying action, protein hydrolysates, glucose, salt solutions, antibiotics, and other resources of directed therapy. Maximum caution must be taken when transfusing blood into such victims, since errors in determining blood type may occur in view of temporary radiation-caused changes in the antigenic properties of erythrocytes (Williams, 1966).

One of the principal methods for treating combined radiation and burn injuries at the time of specialized aid is to replace lost skin. Having systematized the experimental and clinical studies available to him, V. M. Burmistrov (1970) recommends different methods of surgical treatment depending on the severity of thermal trauma.

When the burns are limited in area (not more than 3-5 percent of the body surface) and are dependably known to be deep, early (in the latent period of

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acute radiation sickness) radical necrectomy coupled with concurrent autoplastic correction of the wound defect would be indicated as a rule. If doubt arises as to the viability of the bed of the wound following necrectomy or if the patient's general condition worsens during surgery, allodermatoplasty is performed.

When deep burns are more extensive, initial treatment of the burn wound must be conservative. After demarkation and spontaneous sloughing of necrotic tissues, in the 3d-6th weeks after injury, atraumatic stage-by-stage necrectomy and closure of the wound with a graft would be indicated. During the period of resolution of acute radiation sickness, when the patient's general condition normalizes and the repair and regenerative processes resume in the burn wound, stage-by-stage autoplastic restoration of the skin would be possible; the postage stamp method coupled with temporary covering of the other areas of the wound surface with allodermatotransplants would be preferred. Surgery must be performed in the presence of dependable anesthesia. It should be considered that the response of the irradiated body to administration to painkillers may vary. It has been established that it depends on the chemical composition of the preparation, the severity of radiation injury, and the time since irradiation (P. P. Saksonov et al., 1968). Thus the narcotic effect of barbiturates (hexenal, thiopental sodium, barbamil) weakens within the first hours after radiation injury, and it increases somewhat in the initial and latent periods of acute radiation sickness. At the peak of radiation sickness the sensitivity to barbiturates rises significantly. The narcotic effect of ether rises immediately after irradiation, and subsequently as radiation sickness develops. Anesthesia is deeper and longer-lasting. The usual ether doses may cause severe intoxication at the peak of illness. Nitrous oxide anesthesia proceeds more favorably. This form of anesthesia does not have a negative influence on the course of acute radiation sickness in its various periods. Local anesthesia does not aggravate the course of radiation sickness either, but it does not always produce a painkilling effect at the peak of illness. Ether anesthesia is permissible in the initial and latent periods, but the dose of the administered narcotic must be reduced. Use of ether as an anesthetic at the peak of illness is contraindicated. Nitrous oxide may be used in all periods of radiation sickness. There are no contraindications to the use of local anesthesia in the initial and latent periods of illness, and it can also be employed, with a certain amount of caution, at the peak of radiation sickness.

The postoperative period proceeds the most favorably among persons who had received relatively small radiation doses. Skin autotransplants may take in such victims prior to the peak of radiation sickness. If the latter develops prior to adaptation of the graft, the victim must be placed under close observation, since bleeding from the wound and the addition of infectious complications are possible. Burn victims requiring postponement of surgery make up the most serious group. In these cases the body must be supported with all available resources until the peak of radiation sickness subsides.

Subsequent careful surgical aid during the recovery period is the sole means insuring recovery.

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The methods recommended here for providing aid and therapy are based on the specific features of the pathogenesis and clinical pattern of combined radiation and burn injuries. Naturally, however, they do not exhaust all the variants that may be encountered in the practical activity of rendering aid to a tremendous number of victims with combined injuries in the stages of medical evacuation.

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CHAPTER 4

WOUNDS AND BURNS CONTAMINATED BY RADIOACTIVE PRODUCTS OF A NUCLEAR BURST

Radioactive particles form as a result of condensation of vaporized products of a nuclear burst, as well as the result of their sorption by melted soil particles carried into the cloud by the explosion. As the fireball cools, fused spherical particles form predominantly. The dimensions of such particles produced by aerial nuclear bursts vary within 0.05-10 μ, while those produced by ground bursts are 0.5-1,000 μ. Settling of radioactive particles from the cloud produced by the burst will be noted along the path of traveling air masses. When fallout is local, the terrain becomes dangerously contaminated as a result of ground nuclear bursts due to creation of 20-1,000 μ radioactive particles. The danger of radioactive fallout is practically absent in the case of air bursts because the minute particles are raised to considerable altitude, they scatter in the atmosphere, and they settle slowly over tremendous territory, without creating high radiation levels. It is only when the radioactive cloud of an air burst comes in contact with rain clouds that local fallout can be significant.

Radioactive decay of nuclear burst products is accompanied by the release of corpuscular (alpha- and beta-particles) and electromagnetic emissions (gamma-rays). These emissions are characterized by differing penetrability and ionizing capability (Table 13).

Table 13. Approximate Coefficients of the Penetrability and Ionizing Capability of Alpha- and Beta-Particles and Gamma-Rays

Type of Radiation	Penetrability	Ionizing Capability
Alpha-particles	1	1000
Beta-particles	100	100
Gamma-rays	1000	1

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Despite the high ionization density created, alpha-particles have extremely low tissue penetrability (several microns) and they are of practically no danger when the body surface is contaminated by radioactive substances. These particles are readily blocked by the stratum corneum of the epidermis. Beta-particles, which have a rather high penetrability in body tissues (1-4 mm) and have a high ionization density, cause injury at the place of application of radioactive perticles. At the same time despite their low ionization density, gamma-rays penetrate deeply into body tissues and cause damage to the most radiosensitive tissues (bone marrow cells, intestinal epithelium, and so on), leading to development of radiation sickness. Gamma rays are the principal danger to the body on radioactively contaminated terrain. The contribution of beta-particles to the overall injurious effect of residual radiation is insignificant in view of significant attenuation of their energy by the air layer and clothing, being only 5-10 percent (Dunning, 1959). But in the event of the body's direct contact with the radioactive products of a burst the injurious action of beta-particles rises, especially soon after the burst, while the radioisotopes are producing more beta-particles than gamma-rays.

It has been established by research and computations that the maximum density of contamination of the body surface by the radioactive products of a nuclear burst at which clinically visible skin injuries are not observed is about 2 $\mu Ci/cm^2$.

The body surface becomes radioactively contaminated when an unprotected person is present in the open during formation of the path of the cloud produced by a ground nuclear burst. To assess the real contamination densities that may be encountered we can make use of data from examinations of the residents of the Marshall Islands, who were exposed to the radioactive products of a thermonuclear burst (Table 14).

Table 14. Approximate Ratios Between the Terrain Radiation Level and the Density of Body Surface Contamination by Radioisotopes During Formation of the Path of a Radioactive Cloud

Terrain Radiation Level, r/hr	Skin Contamination Density, $\mu Ci/cm^2$ (million disintegrations per cm^2/min)
1	1.7 (3.7)
10	17 (37.7)
50	85 (188.7)
100	170 (377.4)
200	340 (754.8)

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Comparing the data in Table 14 with the maximally permissible density of body surface contamination (2 $\mu Ci/cm^2$), we find that an unprotected person in a zone of radioactive fallout may be contaminated by radioactive substances even if gamma-radiation on the terrain is relatively low. This means that in a number of cases rather high (injurious) densities of contamination of skin and, consequently, wounds and burns would be observed at general gamma-irradiation doses on the order of just 50-100 r, at which radiation sickness does not usually develop.

Radioactive substances settling on a wound surface may be partially absorbed into the blood and lymph, or they may be adsorbed at their points of contact. But resorption of radioisotopes from fused radioactive particles is negligibly low. Even with their alimentary entrance into the body, total radioisotope assimilation is only about 3 percent of the amount introduced (Le Roy et al., 1965). Iodine radioisotopes, which are characterized by good resorption and are deposited in the thyroid, as well as strontium-89 and strontium-90, which are deposited in bone tissue, may have a certian amount of significance in this regard (Ye. A. Zherbin et al., 1966). On the whole, in the conditions of real war, it would be improbable for the body to be injured by radioactive substances absorbed from wounds (A. A. Vishnevskiy, M.I. Shrayber, 1968).

The bulk of the radioactive perticles remains where they settled in the wound. At particular quantities and with relatively long presence in the wound, they may have an unfavorable influence on the body's living tissues. Disturbance of the course of the wound process stems from injury to tissues that had absorbed the energy of ionizing radiation. When the density of radioactive contaminants is high in the wound, the inflammatory reaction is first instensified and then suppressed new necrotic foci arise, and the sloughing of necrotic tissues is retarded. The wound barrier is weakly pronounced or absent, granulations are pale and hemorrhagic, sometimes they exhibit regression, and epithelialization is retarded.

These features of the development of the wound process promote complication by purulent and sometimes even by anaerobic infection, and slow wound healing. An ulcer forms rather often at the site of the wound, or a scar that has already formed undergoes ulceration.

The injurious action of radioactive substances in the wound channel and on a burn surface has some distinguishing features. These features stem from the differences in the conditions under which radioactive particles come in contact with body tissues.

As was indicated above, the path of beta-particles in body tissues is limited to a few millimeters. This means that when these burns are present, the injurious action of the radioactive substances would be limited to a significant extent to necrotic tissues. In this case the burn scab would play a certain shielding role. Consequently contamination of wounds by radioactive substances would harbor complications of greater seriousness than would burns, under otherwise equal conditions.

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The Specific Features of Therapy

Considering the injurious action radioactive substances have on tissues, it is important to remove them from the wound surface as quickly as possible (L. A. Il'in et al., 1972).

Treatment of wounds and burns must begin with removal of radioactive substances from uninjured skin surrounding the wound (burn). For this purpose the skin should be washed with cotton gauze tampons wetted in a solution of ammonium hydroxide and chloramine.

The recommended way to decontaminate the wound surface is to wash wounds and burns with warm soapy water, physiological or soda solution, 0.5 percent tincture of iodine, and so on. Use of any of these liquids would result in approximately equivalent decontamination, since the latter's mechanism is mechanical removal of radioactive particles. It should be considered in this case that in view of growth in the sorption capability of tissues on the wound surface, it is difficult to wash radioactive substances from it. Thus, for example, it was revealed in an experiment with radioisotopes that after a burn wound is washed with decontaminating agents, the residual radioactivity is about 10 times higher than following decontamination of uninjured skin with the same preparations (Ye. V. Ivanov, M. I. Bokk, 1967). The suitability of implementing the measures indicated above depends to a significant extent on the time since radioactive contamination of wounds and burns. When wounds are washed an hour after contamination, up to 20 percent of the radioactive substances may be removed, about 10 percent may be removed after 2 hours, and from 3 to 5 percent of the radioactive substances may be removed by washing at later times (A. N. Berkutov, 1956). Moreover, as was noted above, the products of a nuclear burst basically have a short half-life, and in view of a natural decline in activity the level of wound contamination drops quickly. We should also consider that washing itself cannot always be thought of as a harmless procedure from the standpoint of, for example, the possibility for spreading radioactive substances and especially infections along the wound channel. Thus as a method of wound and burn decontamination, washing can be employed only in the case of early arrival of victims experiencing high contamination densities. In other cases this method cannot be recommended for broad use (A. A. Gukasyan, V. M. Zhizhin, 1964).

Hygroscopic dressings play an important role in removing radioactive substances from a wound. Such dressings can absorb, together with the wound discharge, up to 50 percent of the radioactive substances settling in the wound.

The most radical removal of radioactive substances involves initial cleansing of the burn surface and initial surgical treatment of the wound. Initial cleansing of a burn is performed in accordance with the commonly accepted rules, coupled with mandatory removal of the sloughed stratum corneum of the epidermis with the goal of removing radioactive substances from the burn surface together with the epidermal fragments. When providing initial

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surgical treatment, it would not make any sense to pursue the goal of completely removing radioactive substances from the wound by excision that is more radical than required by the nature of the wound itself. In some cases (high contamination, the complexity of meticulous initial surgical treatment of the wound) the wound treatment method suggested by A. N. Syzganov (1958) is used additionally to insure more-effective decontamination:

Prior to the beginning of surgical treatment a tourniquet is applied to the limb above the wound. Novocaine mixed with penicillin is injected into the diploe distal to the tourniquet. Infiltrating into the tissues, the solution drains out of the wound. This removes tissue fragments, blood clots, bacteria, and radioactive substances.

Surgical measures can usually remove up to 70-80 percent of the radioactive substances present on the wound surface from it. After such treatment the residual contamination of wounds and burns would be low as a rule. One can make sure of this with dosimetric control. The physician's subsequent tactics would depend on residual wound contamination. If it does not exceed the permissible level, then in the absence of other contraindications the primary sutures can be applied. If the contamination density remains above the permissible level, the wound must be left open. Later, depending on the degree to which wound contamination decreases and the course of the wound process, the question as to applying postponed primary or secondary sutures is resolved.

After surgical aid is rendered, preventive doses of tetanus serum and anatoxin as well as antibiotics with a broad spectrum of action are prescribed to wound and burn victims.

The entire system for rendering aid to victims with burns and mechanical injuries on terrain contaminated by radioactive substances proceeds in stages.

When rendering first medical aid, a dressing must be applied to the burn (wound) as quickly as possible to prevent or reduce settling of radioactive particles on the wound surface.

When rendering first physician's aid, the presence and degree of contamination by radioactive substances are determined from anamnestic data and the readings of dosimetric instruments. All persons contaminated above the permissible level must be immediately subjected to complete or at least partial personal cleansing with the goal of removing radioactive substances from the body surface.

Wounds are not exposed during personal cleansing. Only the upper layers of dressings are removed. After personal cleansing, these casualties are not isolated for separate treatment; instead, they are sent together with all of the rest of the casualties to the different functional subdivisions of the

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particular stage depending on the nature and severity of the burn or wound. First physician's (skilled) aid is rendered to them in the usual volume, though sooner if possible than to casualties not contaminated by radioactive substances. It would be suitable to allocate separate tables in the general surgical and dressing wards for assistance to this group of casualties.

When in satisfactory condition, burn victims undergo cleansing of the burn surface, and then a gauze dressing is applied. If it is impossible to process the burn, it would be suitable to replace the aseptic dressing. The wound discharge would be absorbed by it better, and together with it radioactive substances. If initial surgical treatment of a wound contaminated by radioactive substances cannot be performed at the given stage, the dressing should be replaced with the same goal in mind. All bandaging materials contaminated by radioactive substances are collected in a separate receptacle and later buried in the ground. Instruments, surgical gloves, aprons, and other such articles are decontaminated by meticulous mechanical cleaning with warm water and soap.

The location and severity of thermal or mechanical trauma is the principal criterion followed in evacuating this group of casualties.

On reaching the therapeutic institutions of the hospital base, as in the previous stage, casualties having wounds and burns contaminated by radioactive substances receive aid on priority. At this stage they are provided the full volume of therapy until final recovery.

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CHAPTER 5

TRAUMAS COMBINED WITH BURNS

Burns combined with mechanical traumas are not a new form of war pathology. Such injuries have been observed by surgeons in previous wars as a result of explosion of mines, shells, and bombs close to the victims. A combination of burns and gunshot wounds was noted among 3.9 percent out of the total number of burn victims in the Great Patriotic War of 1941-1945.

Burns combined with mechanical traumas arise in response to the action of the shock wave created by fragments from one or several missiles, as well as from secondary missiles (building fragments, trees) and the resulting fires.

It is extremely difficult to classify this form of combined traumas, since in addition to possessing the unique features of mechanical and thermal traumas, they may occur concurrently and successively. It would be suitable to distinguish between primary burns combined with mechanical traumas, caused by the injurious forces of the initial missile, and secondary burns caused by secondary missiles. The absolute majority of the casualties of the war of 1941-1945 had primary traumas.

Experimental research on injuries arising in response to the concurrent action of thermal and mechanical factors on the same anatomical area established that a combination of superficial burns (degree I, II, and IIIA) and lacerated-contused and bullet wounds cause dermal edema, which is why wounds gape less. The temperature factor has little effect on bleeding. Circulatory disturbances are observed within the injured segment of the limb. The magnitude of primary tissue necrosis does not differ from necrosis arising in ordinary wounds.

When deep burns (degree IIIB-IV) are combined with lacerated-contused and bullet wounds in the same anatomical area, high temperature causes (vybushivaniye) and charring of the skin, approximation of the wound margins, and formation of a hard coagulant on the wound surface. Such wounds do not gape, and they rarely bleed. Blood accumulates in the wound beneath the coagulant; blood clots spread the walls of the wound apart, increasing the

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volume of the cavity. Primary and subsequent necrosis of bone and muscle tissue in the wound is much more extensive than necrosis observed with ordinary wounds. Diffuse circulatory disturbances are observed in tissues around the wound.

Healing of soft tissue wounds accompanied by superficial burns proceeds with significant edema and copious serous discharge. A dry scab readily forms on the wound. Small embedded foreign particles remain superficial predominantly, and they are easily removed or sloughed with purulent discharge. Wound healing takes up to 20 days.

There were some unique features to burns combined with mechanical traumas in the Great Patriotic War of 1945 and in accidental peacetime traumas.

Traumas of the head and face combined with burns are observed among almost half (48 percent) of casualties in this category.

The course of deep facial and head burns combined with mechanical traumas was accompanied by extensive tissue necrosis and frequent infectious complications (meningoencephalitis, osteomyelitis, phlegmons). Skin became necrotic around surgically treated penetrating and nonpenetrating head wounds, causing bones to be exposed. Bone did not become necrotic throughout their entire thickness. As a therapeutic procedure, craniotomy promotes faster rejection of dead bone and growth of granulations in the wound, thus making it possible to prevent complications and complete a skin transplant promptly.

Late skin transplants or failure to carry out this procedure leads to development of disfiguring scars, and it lengthens the treatment time.

There may be difficulties in diagnosing small penetrating wounds of the head combined with deep burns. Every doubtful case would require meticulous neurological examination and roentgenography of the skull.

Severe forms are observed more often in the clinical pattern of cerebral contusions combined with head burns than in the clinical pattern of ordinary closed brain traumas. Pronounced, gross neurological disturbances occur together with edema of facial and head tissues. Recovery occurs in an average of 30 days when closed brain traumas are combined with superficial burns. When combined with deep burns, neurological disturbances disappear by the end of 1 month, and the burn wound healing time depends on the promptness with which a skin transplant is performed.

Traumas of the chest combined with burns made up 6 percent of all traumas combined with burns. Among them, the combination of extensive superficial burns and closed mechanical injuries appear in the greater bulk of the cases. Shock often develops in casualties of this group. It is promoted by extensive burns, serious mechanical trauma, loss of blood, and ventilational hypoxemia.

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It is difficult to diagnose mechanical traumas of the chest combined with burns due to masking of some wounds on the charred skin, and due to distortion of the impression gained from palpation, percussion, and auscultation through charred skin and a dressing. Broader use should be made of X-ray analysis when diagnosing injuries combined with chest traumas.

The healing of surgically treated wounds of the chest combined with superficial burns does not differ from the healing of ordinary wounds.

When chest wounds are combined with extensive deep burns, considerable suppuration develops after surgical treatment, and extensive areas of tissue necrosis arise. Early necrotomy and necrectomy of charred skin would promote reduction of purulent complications and improvement of disturbed respiratory functions. Penetrating thoracic wounds not involving an open pneumothorax but combined with a deep burn are often complicated by empyema of the pleural cavity. Sutured wounds on the chest wall accompanied by an open pneumothorax become purulent in the area of a deep skin burn, and the margins of the wound separate. Patients develop pleural empyema, pneumonia, abscesses, gangrene of the lungs, severe intoxication, sepsis, and other complications, which are the reasons for the poor outcome of treating such traumas.

The course of closed mechanical traumas of the chest with and without injury to internal organs and combined with superficial burns is predetermined by the nature of the mechanical trauma. The combination of mechanical thoracic traumas and extensive deep burns is often complicated by shock and by severe disturbances in respiratory and cardiovascular activity.

Abdominal traumas were observed among 4 percent of casualties with mechanical injuries combined with burns. Extensive superficial burns of the peritoneum combined with penetrating abdominal wounds dominate among casualties of this group. In these cases the body exhibits a general reaction resulting from complications (shock, internal hemorrhaging, quickly developing peritonitis).

It becomes extremely difficult to diagnose penetrating wounds of the abdomen and closed traumas involving injury to internal organs when they are combined with burns. The most invariable symptoms of abdominal penetrating wounds--presence of diffuse pains, dry tongue and thirst, soft and frequent pulse, tensed peritoneal muscles, distended abdomen, and a positive Shchetkin-Blyumberg symptom--may be observed with ordinary peritoneal burns and such burns combined with nonpenetrating abdominal wounds. The absence or weakening of peristaltic noises, presence of fluid in sloping areas of the peritoneal cavity, and bulging out of the wall of the rectum, revealed by rectal examination, acquire great significance to diagnosis of a penetrating wound or a closed trauma of abdominal organs combined with burns. Greater reliance should be placed on roentgenological analysis and laparocentesis with the goal of refining the diagnosis.

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The course of nonpenetrating and penetrating abdominal wounds combined with superficial burns differs little from the course of ordinary wounds. Sutured laparotomic wounds in the area of a superficial burn usually heal without complications.

When nonpenetrating and penetrating peritoneal wounds are combined with extensive deep burns, a pronounced inflammatory reaction coupled with separation of the margins of sutured laparotomic wounds and eventration of the omentum and intestinal loops is observed following surgical treatment. Purulent discharge accumulates in cellular tissue beneath charred skin; this should be prevented by necrotomy and necrectomy. Frequently arising peritonitis is rampaging, with considerable accumulation of fluid in the peritoneal cavity and with very severe intoxication. After the phenomena of peritonitis abate and necrotic tissues are sloughed from the peritoneal wound, huge wound surfaces arise, requiring closure with autotransplants. The outcome of the treatment of this group of severe casualties is often unsatisfactory.

Closed abdominal injuries may be accompanied by contusion of the peritoneum, and they may or may not be coupled with injuries to internal organs. The combination of these traumas with superficial burns changes the clinical pattern of traumas insignificantly. A combination of closed abdominal traumas and deep extensive burns worsens the casualty's general condition and the course of the wound process, and complications often arise. For this group of casualties the postoperative period generally agrees with the clinical pattern observed in the case of abdominal wounds combined with deep burns.

Limb traumas combined with burns made up 40 percent of all injuries combining with burns. In terms of the thermal component of trauma, the frequency of superficial and deep burns is the same for casualties of this group. In terms of the mechanical component of trauma, open injuries dominate over closed ones. The most frequent locations of injury were the hands and the feet. Extensive mechanical destruction of limbs as well as their detachment combine predominantly with superficial burns.

When wounds combined with superficial burns heal, a copious serous and later purulent wound discharge is observed. Circulatory disturbances do not extend beyond the injured segment of the limb, and they disappear later than do circulatory disturbances observed with ordinary traumas. The time of healing of these combined traumas does not differ from the healing time of ordinary wounds and burns.

The healing of gunshot wounds combined with deep burns in the same anatomical area often proceeds with severe complications after surgical treatment. Purulent infection (phlegmons, abscess, accumulations of purulent discharge, lymphadenitis) was observed among 34 percent of the casualties. Limbs had to be amputated often (21 percent) in the presence of traumas complicated by severe infection. Local factors promoting development of complications include excessive tissue destruction and circulatory disturbances in the areas around wounds, hemorrhaging into the wound and into the tissue surrounding it, and arisal of significant secondary necrosis.

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The healing of wounds combined with deep burns depends mainly on the completeness and timeliness of surgical treatment of the wound, on the timeliness of skin transplant, on the correctness of the method chosen for treating bone fractures, and the effectiveness of general therapeutic measures. Scars restricting the function of the limb, articular contractures, and trophic ulcers arise following treatment of mechanical traumas combined with deep burns. The time required for the healing of soft tissues and open (gunshot) bone fractures combined with burns is 2.5-3 times greater than the healing time of ordinary wounds and ordinary burns.

It is difficult to diagnose simple bone fractures when combined with injuries. The principal symptoms of bone fractures are: Pathological mobility, crepitation, deformation in the area of fracture, pains in response to passive movements, and a load placed on the long axis of the limb, the impossibility or limitation of active movements. These symptoms are far from always exhibited by casualties with bone fractures combined with burns, or they are incorrectly read. The reason for difficulties in identifying mechanical injuries combined with burns lies in presence of skin burns and swiftly arising circulatory disturbances in the injured segment of the limb.

The course of closed mechanical limb traumas combined with superficial burns differs little from the course of ordinary traumas. The combination of closed limb traumas and deep extensive burns produced a severe general reaction in the body. Severe shock arises in cases of tissue crushing combined with extensive burns. Casualties of this group exhibit suppuration of hematomas at places of bone fracture, osteomyelitis, and false joints. Secondary displacement of repositioned bone fragments is observed. The healing of a burned surface depends on when necrectomy and skin transplants are performed and on the intensity of general therapy. Persons recovering from such traumas exhibit contractures and knitting of bone fragments in incorrect position, limiting limb function. A combination of closed limb traumas and deep burns compounded by complications means a long time of treatment.

It is difficult to identify soft tissue injuries and bone fractures combined with burns. Early X-ray examination of casualties is required for determination of the nature of injuries accompanying such traumas.

Clinical Pattern

There are general laws governing the manifestations of mechanical traumas combined with superficial burns. Irrespective of the location of such traumas, the course of the mechanical component of trauma changes little in comparison with that of ordinary traumas. When mechanical traumas are combined with deep burns the course of both types of injury worsens, the number of complications grows, treatment time increases, and the outcome of treatment worsens.

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The general changes in the body of a casualty with combined mechanical and thermal traumas are expressed variously. In the bulk of the group of casualties with superficial combined with mechanical traumas, severe general reactions are predominantly the product of the mechanical component of trauma, and they are observed no more frequently than with ordinary wounds. When mechanical traumas are combined with deep burns of even small surface area (less than 10 percent of the body surface), the frequency of severe reactions increases. Shock is observed in 21.6 percent of casualties suffering such a combination of traumas. Shock arises in 2 percent of casualties with ordinary burns (Yu. Yu. Dzhanelidze, B. N. Postnikov, 1952), while traumatic shock is observed in 1.9 percent of casualties with upper limb wounds, 7.8 percent of casualties with lower limb wounds (S. I. Banaytis, 1948), and 72 percent of casualties with abdominal wounds (A. A. Bocharov). Significant shifts occurring in the casualty's body in response to the combination of thermal and mechanical trauma lead to development of severe burn disease. When accompanying traumas combine with superficial burns, shock proceeds as traumatic shock. The combination of deep burns and traumas causes arisal of burn shock. The specific traits of the latter may be indistinct due to blood loss and the relatively small area of the deep burn. The clinical manifestations of shock are severe. The erectile phase is either absent or short. The torpid phase of shock arises after trauma, and it is characterized by arterial hypotension, a rapid weak pulse, oliguria, reduced body temperature, and vomiting. Duration is an important criterion of shock. Two-thirds of the casualties with combined deep burns and mechanical trauma recover from shock on the 2d and 3d days after trauma.

In the second period of burn disease--burn toxemia--body temperature rises, the pulse is rapid and weak, vomiting is recurrent, and motor arousal alternates with sleepiness. The severe manifestations of toxemia last for 3-10 days.

The third period of burn disease--burn septicotoxemia--is the product of a combination of burn toxemia deteriorating to a subacute course and purulent-resorptive fever (A. A. Vishnevskiy, M. I. Shrayber, 1968). Extensive tissue necrosis, rampaging wound inflammation, and complication of wounds significantly aggravate the course of this period of disease when traumas are combined with burns.

When burns are accompanied by mechanical trauma the convalescent period lasts two to three times longer than the convalescent period following ordinary burns or ordinary wounds.

Consequently the combination of thermal and mechanical traumas in the same anatomical area means severer injury. Shock proceeds predominantly with severe clinical manifestations.

Principles of Therapy

The bulk of casualties with combined mechanical and thermal traumas exhibit a combination of soft tissue injuries and superficial burns, which usually

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has little effect on the general condition of the casualties. This is why the general therapeutic measures applied to this group of casualties are limited to administration of antibiotics and vitamins and provision of a balanced diet.

Changes occur in the general condition of casualties in response to superficial burns combined with severe mechanical traumas as well as in response to deep burns combined with traumas. Changes in the general condition of casualties generally require implementation of the same sort of therapeutic measures used in relation to ordinary traumas.

Surgical treatment of the wound continues to be the main resource for preventing wound infection.

Treatment of wounds combined with burns begins with cleaning the burn surface. First hair is shaved from the area around the burn. After covering the bone and muscle wound with a sterile napkin, the burned surface is cleaned with tampons wetted in 0.25 percent ammonium hydroxide solution. Fragments of epidermis sticking to portions of clothing, and other foreign particles are removed. The treated burn surface is covered with a sterile napkin, and then the wounded bone and muscle tissue is subjected to physical treatment in accordance with the general rules. Treatment of the wound ends with infiltration of its walls with antibiotic solution.

One unique feature is the need for excising tissues much more carefully then with ordinary wounds due to the large zone of primary tissue necrosis. The volume of the operation is larger due to additional dissection required in the presence of sloughed skin, hemorrhaging, arisal of slits and "pockets" inside tissues, and due to the need for necrotomy. Bleeding from tissues may be intense during surgery, resulting in greater blood loss than with treatment of ordinary wounds.

The surgical tactics of treating wounds combined with burns of different degrees vary. When wounds are accompanied by superficial burns the therapy depends mainly on presence or absence of suppuration on the burn surface, as well as on the nature of mechanical trauma. After wounds of the head, chest, and abdomen are surgically treated through burned skin (degree I, II, IIIA), they should be sutured shut, as the indications require. Most casualties with such traumas are treated with ointment dressings after surgical treatment. After the burned surface heals, postponed sutures are applied to the wound.

The surgical tactics of treating wounds combined with deep burns depend not only on the degree of infection and the nature of mechanical trauma but also on the area and location of the burn as well as on the victim's general condition. When deep burns of small area are combined with a wound and when infection is absent, early one-time surgical treatment coupled with excision of necrotic skin and tissues in a bone-muscle wound would be suitable. The operation may end with application of sutures, plastic correction of the

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skin defect, or with leaving the wound open for later application of secondary sutures or for a skin transplant.

Surgical treatment of wounds combined with deep burns of considerable area proceeds in several stages. The reason for this lies in the biological properties of tissues (the impossiblity of determining the depth of skin necrosis soon after trauma) as well as in the traumatic nature of an operation performed all at one time. Surgery is first performed on penetrating wounds; tissues in the bone and muscle part of the wound are dissected and excised, the burn surface is cleaned and burned skin is subjected to necrotomy as necessary. Early necrectomy of dead skin and plastic correction of skin defects follow next.

When deep burns of the head are combined with mechanical traumas, bones may be injured. Craniotomy would be indicated in these cases.

The craniotomy procedure: Holes penetrating to healthy bone are drilled into injured bone. Appearance of bone lightly stained with blood in the drill hole would be a sign that uninjured bone had been reached. The bridges between the holes are chipped out with a chisel, and the sequestrum is removed. After removal of the sequestrum, granulations on the skull are covered over with a pedicle graft using local tissue and the Italian method of plastic surgery, or using a Filatov panniculus or a split autodermal graft.

Chest wounds involving an open pneumothorax are sutured to the point where burned skin is reached. Considering the frequent infectious complications of wounds, a thoracotomy is performed and a permenent drain tube is installed. When the burns are of limited area an atypical panniculus outside the burn area can be used for the thoracotomy. When burns are extensive the thoracotomy is performed through burned skin. Pleural punctures through burned skin should be employed predominantly for diagnostic purposes. Multiple punctures promote infection of the pleural cavity; this is why a suppurative hemothorax should be identified promptly and a thoracotomy should be performed to install a permanent drain tube. It is especially important to perform a necrectomy and a skin transplant early on all casualties with chest wounds combined with deep burns, since the burns are often of considerable size, and they often become complicated by wound emaciation. Before wound emaciation develops the wound surface must be covered over with an autodermal graft.

Casualties with burned respiratory passages or multiple rib fractures combined with circumferential burns will require a tracheostomy if complications arise.

When penetrating wounds of the abdomen are combined with extensive deep burns, a laparotomy is performed through burned skin. The laparotomic wound is sutured to the point where burned tissue is reached. When deep peritoneal burns of small area are combined with penetrating abdominal

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wounds, an atypical incision can be made through unburned skin. Gunshot wounds penetrating into the abdomen and combining with burns of the peritoneum are subjected to surgery in accordance with the general rules. The possibility that the margins of the laparotomic wound might separate owing to suppuration makes is necessary to apply sutures embracing a broad area of the aponeurosis, and to apply bandages over the abdomen restricting excursions of the peritoneum. In the second stage of treatment granulating wounds of the peritoneum are covered over with autodermal grafts.

Limb wounds combined with extensive deep wounds are treated in two stages. Surgical treatment can be performed all at one time when the combination consists of a small deep burn and a wound as well as when extensive mechanical tissue destruction or limb separations are combined with a deep burn. When necessary, limbs are amputated level with uninjured tisses, and the wound on the stump is not sutured. The operation should be performed before development of severe intoxication and complications.

Covering granulating wounds, expecially those in functionally active areas, articular surfaces primarily, has important significance to the treatment of limb wounds combined with extensive deep burns. Surgical treatment is provided to bone fractures that fail to knit and to false joints (secondary osteosynthesis, osteoplasty) later, after the wounds heal.

When combined with burns, wounds of all locations that had been subjected to surgery are subsequently treated as closed wounds. Minute irrigation tubes are introduced into surgically treated wounds in order to permit constant irrigation by antibiotic solutions, hypertonic table salt solution, or enzymes. A. V. Vishnevskiy's oil-balsam burn-treating emulsion, syntho-mycin and streptocide emulsions, and furacillin ointment are used; napkins are saturated with these compounds and packed loosely into bone and muscle wounds, and they are placed over burned skin.

When closed mechanical traumas are combined with superficial burns in the same anatomical area, dislocated limb segments must be set and bone fragments must be repositioned early, before development of tissue edema and infection. When infection and edema develop, all manipulations become dangerous and comlicated owing to the possibility of pinching tissues between bone ends. Dislocations are set and bone fragments are repositioned after the burned surface is cleansed and covered with a sterile bandage. After the bone fragments are repositioned and a dislocation is set, an ointment dressing is applied.

When closed mechanical traumas are combined with deep burns of limited area, if the indications allow, a limb can be dissected to permit open repositioning of bone fragments and osteosynthesis; surgical entry can be achieved outside the burn area or through it, after first excising burned tissue. The surgical wound should be closed with primary sutures or covered with an autodermal graft cut with a dermatome.

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The method of anesthesia depends on the nature of traumas, the general condition of the victim, and the sort of surgery to be performed. Local infiltrational anesthesia with novocaine, intraosteal anesthesia, and improved methods of general anesthesia can be employed.

In each case of treatment of compound (gunshot) and simple fractures combined with burns on the same place, immobilizing a limb is a complex problem. When a bone fracture is combined with a superficial burn or a deep burn of limited area, it would be a good idea to apply plaster splints and dead-end plaster casts after repositioning the bone fragments. When a fracture is combined with extensive and circumferential burns, skeletal traction would provide the most convenient condition for treatment and care. The unique features of the course of fractures combining with burns as well as the conditions of war sharply restrict the possiblities for primary osteosynthesis. The compressional-distractional method, developed in recent years and making use of Ilizarov's, Sivash's, and Gudushauri's apparatus, will enjoy application in the stage-by-stage treatment system for the treatment of bone fractures combined with burns.

Consequently when mechanical traumas are combined with burns, the entire treatment process becomes more complex. Incompatability of individual elements of therapy, which is a problem that is difficult to solve, is often encountered during treatment (A. A. Vishnevskiy, M. I. Shrayber, 1968).

The principles of stage-by-stage treatment of this form of injury correspond to the general principles, with a consideration for the unique features presented above.

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